COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

No. 75 — April 2002 Editor: Steve Skinner (coolnews@jila.colorado.edu)

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Stellar Abstracts

UVES Be Observations of Early–G Dwarfs in Old Clusters

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We have obtained the first beryllium measurements of late F/early G–type stars in the old open cluster M67 (4.5 Gyr) and in the intermediate age cluster IC 4651 (1.7 Gyr). One member of the young cluster IC 2391 ($\sim$ 50 Myr) was also observed. Our sample stars have effective temperatures within a range of $+30 - +380$ K from the solar temperature. All our sample stars, including the Sun and the young cluster star have, within the errors, the same Be abundance. This result implies that late F/early G–type stars undergo very little (if any) Be depletion during their main-sequence life-time. Since these stars have undergone some Li depletion, our finding is indicative of shallow mixing, i.e. of a mixing process that can transport surface material deep enough for Li burning to occur, but not deep enough for Be burning. As shown in previous studies, the Li vs. Be diagram is a powerful diagnostic of stellar interiors. In this context, we do not find any evidence of correlated Li and Be depletion; furthermore, a comparison with various models shows that the Be pattern of our sample stars is compatible only with models including gravity waves. This class of models, however, cannot reproduce the Li observations of M 67.

Accepted by A&A

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The Outer Atmosphere of the M-type Supergiant α Orionis: K I 7699Å Emissio

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patially-resolved high-resolution long-slit spectra of Betelgeuse's circumstellar shell are described for a spectral window centered on the 7699Å resonance line of neutral potassium. The K I emission from resonance fluorescent scattering of photospheric photons which is mapped out to 50 arcsec from the star is approximately spherically symmetric with a brightness decreasing as $r^{-2.36\pm0.03}$, where r is the radial distance from the star. Our measurements together with the earlier theoretical interpretation by Rodgers & Glassgold suggest that the mass loss rate is about 2 $\times 10^{-6}$ $M_\odot$ y^{-1}. The K I emission is far from homogeneous: intensity inhomogeneities are seen down to the seeing limit of about 1 arcsec and the velocity resolution of about 2 km s^{-1}. There is clear evidence for a thin shell of 50 arcsec radius. This is identified with the weaker circumstellar absorption component known as S2. Estimates are made of the density of K atoms in this shell ($\simeq 6 \times 10^{-5}$ cm^{-3}).

Accepted by A&A

For preprints via ftp or WWW: http://xxx.lanl.gov/abs/astro-ph/0203209

Measured Mass Loss Rates of Solar-like Stars as a Function of Age and Activity

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Collisions between the winds of solar-like stars and the local ISM result in a population of hot hydrogen gas surrounding these stars. Absorption from this hot H I can be detected in high resolution Lyα spectra of these stars from the *Hubble Space Telescope*. The amount of absorption can be used as a diagnostic for the stellar mass loss rate. We present new mass loss rate measurements derived in this fashion for four stars (ϵ Eri, 61 Cyg A, 36 Oph AB, and 40 Eri A). Combining these measurements with others, we study how mass loss varies with stellar activity. We find that for the solar-like GK dwarfs, the mass loss per unit surface area is correlated with X-ray surface flux. Fitting a power law to this relation yields $\dot{M} \propto F_x^{1.15\pm0.20}$. The active M dwarf Proxima Cen and the very active RS CVn system λ And appear to be inconsistent with this relation. Since activity is known to decrease with age, the above power law relation for solar-like stars suggests that mass loss decreases with time. We infer a power law relation of $\dot{M} \propto t^{-2.00\pm0.52}$. This suggests that the solar wind may have been as much as 1000 times more massive in the distant past, which may have had important ramifications for the history of planetary atmospheres in our solar system, that of Mars in particular.

Accepted by ApJ

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Differential Rotation of Cool Active Stars: The Case of Intermediate Rotators

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In this paper, we present a new method for measuring the surface differential rotation of cool stars with rotation periods of a few days, for which the sparse phase coverage achievable from single site observations generally prevents the use of more conventional techniques. The basic idea underlying this new analysis is to obtain the surface differential rotation pattern that minimises the information content of the reconstructed Doppler image through a simultaneous fit of all available data.

Simulations demonstrate that the performance of this new method in the case of cool stars is satisfactory for a variety of observing strategies. Differential rotation parameters can be reliably recovered as long as the total data set spans

at least 4% of the time for the equator to lap the pole by about one complete cycle. We find in particular that these results hold for potentially complex spot distributions (as long as they include a mixture of low and high latitude features), as well as for various stellar inclination angles and rotation velocities. Such measurements can be obtained from either unpolarised or polarised data sets, provided their S/N ratio is larger than about 500 and 5000 per 2 $\mathrm{km\,s^{-1}}$ spectral bin respectively.

This method should therefore be very useful to investigate differential rotation in a much larger sample of objects than what has been possible up to now, and should hence give us the opportunity of studying how differential rotation reacts to various phenomena operating in stellar convective zones, such as tidal effects or dynamo magnetic field generation.

Accepted by MNRAS

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Chandra LETGS Observation of the Active Binary Algol

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A high-resolution spectrum obtained with the low-energy transmission grating onboard the Chandra observatory is presented and analyzed. Our analysis indicates very hot plasma with temperatures up to $T \approx 15-20\,\mathrm{MK}$ from the continuum and from ratios of hydrogen-like and helium-like ions of Si, Mg, and Ne. In addition lower temperature material is present since O VII and N VI are detected. Two methods for density diagnostics are applied. The He-like triplets from N VII to Si XIII are used and densities around $10^{11}\,\mathrm{cm^{-3}}$ are found for the low temperature ions. Taking the UV radiation field from the B star companion into account, we find that the low-Z ions can be affected by the radiation field quite strongly, such that densities of $3\times10^{10}\,\mathrm{cm^{-3}}$ are also possible, but only assuming that the emitting plasma is immersed in the radiation field. For the high temperature He-like ions only low density limits are found. Using ratios of Fe XXI lines produced at similar temperatures are sensitive to lower densities but again yield only low density limits. We thus conclude that the hot plasma has densities below $10^{12}\,\mathrm{cm^{-3}}$. Assuming a constant pressure corona we show that the characteristic loop sizes must be small compared to the stellar radius and that filling factors below 0.1 are unlikely.

Accepted by A&A

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ess.

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ROSAT PSPC/HRI Observations of the Open Cluster NGC 2422

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We present the results of a ROSAT study of NGC 2422, a southern open cluster at a distance of about 470 pc, with an age close to the Pleiades. Source detection was performed on two observations, a 10-ksec PSPC and a 40-ksec HRI pointing, with a detection algorithm based on wavelet transforms, particularly suited to detecting faint sources in crowded fields. We have detected 78 sources, 13 of which were detected only with the HRI, and 37 detected only with the PSPC. For each source, we have computed the $0.2-2.0$ keV X-ray flux. Using optical data from the literature and our own low-dispersion spectroscopic observations, we find candidate optical counterparts for 62 X-ray sources, with more than 80% of these counterparts being late type stars. We have assigned to the optical sources an astrometric and/or a photometric membership flag, depending on which data are available to us. The number of sources (38 of 62) with high membership probability counterparts is consistent with that expected for Galactic plane observations

at our sensitivity. We have computed maximum likelihood X-ray luminosity functions (XLF) for F and early-G type stars with high membership probability. Heavy data censoring due to our limited sensitivity permits determination of only the high-luminosity tails of the XLFs; the distributions are indistinguishable from those of the nearly coeval Pleiades cluster.

Accepted by A&A

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Solar Abstracts

Effects of Hysteresis in Solar Cycle Variations Between Flare Index and Some Solar Activity Indicators

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We show that smoothed time series of some solar activity indicators exhibit significant hysteresis, i.e. they have solar cycle dependent differences in their relative variations during the past three solar cycles 20, 21, and 22. This implies that the shapes and the directions of these differences vary from cycle to cycle, while a saturation effect exists at extreme phases. The choice of activity indicator versus flare index may strongly influence the resulting hysteresis in a given solar cycle. Therefore these observed hysteresis patterns may not give evidence that this is a normal feature of solar variability.

Accepted by Adv. Space Res.

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Chromospheric Models of a Solar Flare Including Velocity Fields

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We study the chromospheric structure of a small flare, before, during and after the first hard X-ray spike. We construct 5 semiempirical models for different times, which will reproduce the profiles of the H_δ, Ca II K and Si I 3905 lines during the flare evolution. In order to reproduce the intensity and the main characteristics of the line asymmetry we introduce the velocity fields in the profile calculations. We find that the whole chromosphere undergoes a strong upward motion within 1 s of the maximum of the first hard X-ray spike, when the temperature and the density begin to rapidly increase. This seems the first chromospheric response to the energy deposition and/or release. Only 6 s after the hard X-ray peak, a strong downflow begins in the low chromosphere and its velocity continues to increase even during the cooling phase.

Accepted by AA

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Line Formation in Convective Stellar Atmospheres. I. Granulation Corrections for Solar Photospheric Abundances

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In an effort to estimate the largely unknown effects of photospheric temperature fluctuations on spectroscopic abundance determinations, we have studied the problem of *LTE line formation in the inhomogeneous solar photosphere* based on detailed 2-dimensional radiation hydrodynamics simulations of the convective surface layers of the Sun. By

means of a strictly differential 1D/2D comparison of the emergent equivalent widths, we have derived *"granulation abundance corrections"* for individual lines, which have to be applied to standard abundance determinations based on homogeneous 1D model atmospheres in order to correct for the influence of the photospheric temperature fluctuations. In general, we find a *line strengthening* in the presence of temperature inhomogeneities as a consequence of the non-linear temperature dependence of the line opacity. The resulting corrections are negligible for lines with an excitation potential around $E_i = 5$ eV, regardless of element and ionization stage. Moderate granulation effects ($\Delta_{\rm gran} \approx -0.1$ dex) are obtained for weak, high-excitation lines ($E_i > 10$ eV) of C I, N I, O I as well as Mg II and Si II. The largest corrections are found for ground state lines ($E_i = 0$ eV) of neutral atoms with an ionization potential between 6 and 8 eV like Mg I, Ca I, Ti I, Fe I, amounting to $\Delta_{\rm gran} \approx -0.3$ dex in the case of Ti I. For many lines of practical relevance, the magnitude of the abundance correction may be estimated from interpolation in the tables and graphs provided with this paper. The application of abundance corrections may often be an acceptable alternative to a detailed fitting of individual line profiles based on hydrodynamical simulations. The present study should be helpful in providing upper bounds for possible errors of spectroscopic abundance analyses, and for identifying spectral lines which are least sensitive to the influence of photospheric temperature inhomogeneities.

Accepted by A&A

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Low-Mass and Substellar Abstracts

Activity at the Deuterium-Burning Mass Limit in Orion

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We report very intense and variable Hα emission (pseudo-equivalent widths of ~ 180 and 410 Å) of S Ori 55, a probable free-floating, M9-type substellar member of the young σ Orionis open star cluster. After comparison with state-of-the-art evolutionary models, we infer that S Ori 55 is near or below the cluster deuterium-burning mass borderline, which separates brown dwarfs and planetary-mass objects. We find its mass to be 0.008–0.015 $M_\odot$ for ages between 1 Myr and 8 Myr, with $\sim$0.012 $M_\odot$ the most likely value at the cluster age of 3 Myr. The largest Hα intensity reached the saturation level of $\log L_{\rm H\alpha}/L_{\rm bol} = -3$. We discuss several possible scenarios for such a strong emission. We also show that σ Orionis M and L dwarfs have in general more Hα emission than their older field spectral counterparts. This could be due to a decline in the strength of the magnetic field with age in brown dwarfs and isolated planetary-mass objects, or to a likely mass accretion from disks in the very young σ Orionis substellar members.

Accepted by ApJ Letters

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For preprints via ftp or WWW: http://xxx.lanl.gov/abs/astro-ph/0203283

High-resolution X-ray Plasma Diagnostics of Stellar Coronae

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Ph.D degree awarded: March 2002

With the discovery of sunspots in the 17^{th} century a new field of work in Astronomy was opened. The physical origin of these dark spots on the solar surface has been found to be tightly connected with the presence of strong magnetic fields. Another spectacular phenomenon is the solar corona, the outermost region of the Sun. The high temperature found in the corona in connection with a very low density has posed a lot of questions. Again, the magnetic activity of the Sun seems to play a fundamental role in controlling the processes observed in the solar corona. An introduction for a long tradition of observing the solar corona especially in the X-ray wavelength band is given in this work. Starting with earth-bound observations of the visible corona, and proceeding with spectral diagnostics, impressive pictures with high spatial resolution are presented. A detailed structure with the distribution of the coronal plasma, obviously confined to loop-like structures following closed magnetic field lines, is seen on these pictures.

As a far more difficult task, the observation of stellar coronae, which are not spatially resolvable, is introduced. From X-ray observations carried out with the satellites Einstein and ROSAT it is known that the formation of coronae must be a common phenomenon in all late-type stars that occurs at the transition from a cool star's photosphere to space. A classification of X-ray properties similar to a Hertzsprung-Russell diagram connecting X-ray emission with fundamental stellar parameters is desirable, but only the rotation of cool stars has so far been found to be connected with X-ray emission.

New approaches can be made using the recent X-ray missions Chandra and XMM, which allow high spectral resolution. The emission lines observable with these missions are used for deriving physical properties of the coronae of Capella, Algol, and Procyon. Four more cool stars are analyzed, but in less detail. A special software has been developed in the frame of this work, the algorithm being especially dedicated to Chandra LETGS spectra, but also useful for all kinds of spectral data, e.g., XMM-RGS.

Preliminary analysis of the spectra yields a distribution of plasma layers with different properties, e.g., temperatures. At least a high temperature and a low temperature component is found for the active stars Algol and Capella, but not for the inactive star Procyon. Optical depth effects seem to be negligible, such that the basic assumption of an optically thin plasma is justified at least within the scope of the current data. The continuum of Algol's coronal X-ray spectrum can be fitted by a bremsstrahlung continuum, and an upper temperature as well as an emission measure are derived from the analysis of the continuum.

The main focus of this work is the application of the method of He-like triplets for deriving plasma densities. The coronal plasmas for Capella, Procyon, Algol, ϵ Eri, α Cen A and B, and UX Ari are probed. I generally find low densities for most of these seven stars and higher densities only for ϵ Eri and Algol. For Algol this result depends, however, on the influence of the UV radiation field emitted by the B star companion. No convincing trend could be found allowing the general conclusion of higher densities in more active stars. It is noteworthy, however, that active stars with lower densities as e.g., Capella are all RS CVn systems, i.e., binaries comprising two cool stars, possibly each of them sustaining a hot corona. An interaction between these two coronae is well conceivable. Quite convincing though is the trend of the presence of hot plasma in the more active stars, while inactive stars only have a "cool" component around 2 MK. (*...cont.* →)

At low densities constraints on parameters connected with structural information as, e.g., the loop scale length or filling factors can be made. That information enables us to compare stellar coronae with the solar corona. The densities measured for the solar corona are comparable with densities measured in inactive stars. Loop scale lengths can therefore be assumed to be very similar to the Sun, such that the structural properties of these coronae are likely the same as observed for the Sun. A different picture must be drawn for the more active stars, which have to accommodate the higher emission measure either in structures with similar sizes but higher densities, or they are characterized by a plasma distribution with higher filling factors. An isolated active corona as, e.g., in the Algol system seems to prefer the first option, while RS CVn systems can well harbor a binary corona with a large volume and low densities. Therefore these two configurations must be treated differently.

Thesis-related Publications: A&A 367, 282 (2001); A&A accepted (2002); http://www.sub.uni-hamburg.de/disse/616/

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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