// COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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Stellar Abstracts

Radio, X-ray, and EUV Coronal Variability of the Short-Period RS CVn Binary σ^2 Coronae Borealis

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We present the results of a coordinated observing campaign on the short-period (1.14 day) RS CVn binary σ^2 Coronae Borealis with the VLA, *ASCA*, and *RXTE*. We also discuss earlier observations of the same system obtained by *EUVE*. Dramatic coronal variability is present in all of these observations across the electromagnetic spectrum. σ^2 CrB undergoes frequent large flares which occur close together in time. Radio flares are unambiguously correlated with X-ray flares; the X-ray flares peak as much as 1.4 hours before the corresponding radio maxima. Response to flares is more rapid in higher energy X-ray bandpasses, signalling an increase in temperature during the course of the flare. Flares are seen more frequently in the harder *RXTE* bandpass than in simultaneously taken *ASCA* observations. There is greater contrast between flaring and nonflaring conditions in the *RXTE* light curve. Complex flaring is seen in the radio at 3 and 6 cm, consistent with optically thin nonthermal gyrosynchrotron emission for most of the duration of the observation. Bursts of left circularly polarized emission at 20 cm lasting $\leq$ 15 minutes appear to be due to a coherent emission process. *EUVE* spectra reveal coronal material at $n_e \leq 10^{12}$ cm^{-3}, with no discernible density differences between flaring and quiescent time intervals. Quiescent *ASCA* spectra show lower than solar photospheric abundances with iron depleted by a factor of four from the solar photospheric value. The abundances increase during a large flare observed with *ASCA*, with iron enhanced to the solar photospheric value during the rise phase of the flare. Two temperature fits to extracted spectra show a low temperature quiescent value of 8 MK, and a high temperature component that varies from 22 MK during quiescence to 50 MK at the peak of the flare. Emission measure distributions measured from the *ASCA* observations are consistent with the temperatures derived from the discrete two temperature fits, and indicate the presence of very hot (> 100 MK) plasma during the rise phase of the *ASCA* flare. Many of the flares observed with *EUVE*, *ASCA*, *RXTE* show a double exponential decay phase, further highlighting the importance of this phenomenon in diagnosing flaring conditions. We also find that the observed second decay time scale cannot be explained by some of the currently used flare parameterizations.

Accepted by ApJ

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Study of FK Comae Berenices. II. Spot Evolution from 1994 to 1997

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We present new surface (Doppler) images of the late-type single giant FK Com for June-July 1996, July-August 1996, April 1997 and June 1997. These images are compared with the previously published images from 1994 and 1995. The consecutive maps are cross-correlated to see the possible migration of the spots and the effects of differential rotation. The cross-correlation confirms an average longitudinal spot migration of 0.22 ± 0.03 in phase within a year. This movement is probably an artifact caused by a difference between the accepted rotation period and the real photometric period for these years. If this is true, then the photometric rotation period for these years is $2^{\rm d}\!.4037 \pm 0.0005$. Measurements from these four years and six maps limit the surface differential rotation to $\alpha = 0.0001 \pm 0.0002$, where α is the difference between polar and equatorial angular velocities relative to the equatorial angular velocity.

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X-ray Emission from Young Stars in the Tucanae Association

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We report on X-ray emission from members of the recently discovered Tucanae association, a group of stars with youth signatures and similar space motion. The Tucanae association is the nearest known region of recent star formation (~ 45 pc) far from molecular clouds. We have made use of the *ROSAT* Data Archive and searched for X-rays from Tucanae stars in both *ROSAT* All-Sky Survey (RASS) and pointed observations. The RASS provides complete sky coverage. Thus all potential Tucanae members have been observed. The detection rate is 59%. Three stars from the Tucanae association were also observed in PSPC pointings.

We compare the X-ray luminosity function of the Tucanae association to that of other star forming regions and young star clusters. Since the X-ray luminosity is known to decline with stellar age this allows to constrain the age of the Tucanae stars. The X-ray luminosity function suggests an age of $\sim 10-30$ Myrs for this association. Strong variability observed in the X-ray lightcurves further supports the youth of these stars.

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Modeling the Variable Chromosphere of α Orionis

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A spectral analysis of the prototypical red supergiant star α Ori is presented that is based on near-UV, optical, and near-IR high-dispersion spectra obtained between 1992 September and 1999 July with the Space Telescope Imaging Spectrograph and the Goddard High Resolution Spectrograph on the *Hubble Space Telescope*, the Utrecht Echelle

Spectrograph and the SoFin Spectrograph. With detailed NLTE radiative transfer calculations in spherical geometry we model the mean conditions in the stellar chromosphere from Hα and the Mg II resonance doublet. The Hα absorption line emerges from an extended chromosphere.

Temporal changes of its velocity structure are determined from detailed fits to near-UV Si I lines, and chromospheric expansion velocities around 4 km s^{-1} are found in 1992, whereas the chromosphere was collapsing onto the photosphere with a velocity of 5 km s^{-1} in 1998$-$1999. The Hα core depth is correlated over time with weaker depression changes seen in prominent TiO band-heads that dominate the optical spectrum. From elaborate spectral synthesis calculations we isolate unblended metal absorption lines in the near-IR and determine $T_{\rm eff}$=3500 K and log(g)=$-$0.5 for solar metallicity and 12$\pm$0.5 km s^{-1} for macrobroadening and $v$sin$i$. Semi-empirical fits yield chromospheric temperatures not in excess of 5500 K, but with long-term changes by $\sim$400 K. The model extends out over 5000 $R_\odot$ and requires supersonic microturbulence values ranging up to 19 km s^{-1}, in strong contrast with the photospheric value of only 2 km s^{-1}.

We observe Doppler shifts of 4 to 8 km s^{-1} in the scattering cores of many double-peaked near-UV emission lines which correlate with changes in the intensity ratio of their emission components. The red emission components were much stronger in 1992, indicating a phase of enhanced chromospheric outflow for which we determine a spherical mass-loss rate of 6×10^{-7} $M_\odot$ yr^{-1}. We present a discussion of chromospheric pulsation in this massive star. Detailed modeling of the observed Mg II h & k line asymmetry is also presented. We demonstrate that a chromospheric Mn I blend strongly contributes to this puzzling asymmetry.

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Stability of Magnetic Flux Tubes in Close Binary Stars

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Photometric and Doppler imaging observations of active binaries indicate the existence of starspots at preferred longitudes (position angles with respect to the companion star). We investigate the stability of magnetic flux tubes in the convection zone of close, fast-rotating binary stars and explore whether the observed preferred longitudes could be caused by tidal forces and the deformation of the active star. We assume a synchronized binary system with spin axes perpendicular to the orbital plane and a rotation period of a few days. The tidal force and the deviation from spherical structure are considered in lowest-order perturbation theory. The magnetic field is in the form of toroidal magnetic flux rings, which are stored in mechanical equilibrium within the stably stratified overshoot region beneath the convection zone until the field has grown sufficiently strong for the undulatory instability to initiate the formation of rising loops. Frequencies and geometry of stable as well as growth rates of unstable eigenmodes are determined by linear stability analysis. Particular consideration is given to the question whether the effects of tidal forces and perturbations of the stellar structure can force a rising flux loop to enter the convection zone at specific longitudes.

Accepted by Astronomische Nachrichten

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Chemical Analysis of 8 Recently Discovered Extra-solar Planet Host Stars

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We present the chemical analysis of a new set of stars known to harbor low mass companions, namely HD 1237, HD 52265, HD 82943, HD 83443, HD 169830, and HD 202206. In addition, we have also analyzed HD 13445 and HD 75289, already studied elsewhere. The abundances of C and α-elements O, S, Si, Ca and Ti are presented and discussed in the context of the metallicity distribution of the stars with extra-solar planets. We compare the metallicity distribution of stars with planets with the same distribution of field dwarfs. The results further confirm that stars with planets

are over-abundant in [Fe/H]. The origin of the metallicity excess is discussed.

Submitted to A&A

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The CORALIE Survey for Southern Extra-solar planets. IV. Intrinsic Stellar Limitations to Planet Searches with Radial-velocity Techniques

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Activity related phenomena can induce radial-velocity variations, which can be very important when dealing with extra-solar planet search programs requiring high-precision radial-velocity measurements.

In this paper we present a new chromospheric activity index, S_{COR}, based on the CaII H line central reemission, and constructed using CORALIE spectra. After one year of measurements, values of S_{COR} are available for a sub-sample of stars of the Geneva extra-solar planet search programme. After transforming the S_{COR} values into the Mount-Wilson "S" scale we obtained values of the CaII H and K flux corrected from photospheric emission (R'_{HK}) for the stars.

The first results are presented, and in particular we focus on the study of the relation between the observed radial-velocity scatter and the chromospheric activity index R'_{HK}, for F, G and K dwarfs.

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X-ray Source Populations in the Region of the Open Clusters NGC 6633 and IC 4756

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Using deep exposures ($\sim 10^5$ s) with the *ROSAT* HRI, we have performed flux-limited surveys for X-ray sources in the vicinity of the Hyades-age open stellar clusters NGC 6633 and IC 4756, detecting 31 and 13 sources respectively. Our primary aim is to search for so-far unrecognised cluster members. We propose identifications or classifications (cluster member, field star, extragalactic field object) for the X-ray sources, based on published membership lists, and on X-ray:optical flux ratios and optical colour–magnitude diagrams. Results of simulating the expected X-ray-emitting source populations are compared with the *ROSAT* measurements and with the expected capabilities of the *XMM* mission. The simulations provide a novel method of comparing the activity levels of NGC 6633 and IC 4756 with that of the Hyades. The measurements and simulations confirm that cluster members are the major class of X-ray emitter in these fields at flux levels $f_{\mathrm{X}} \gtrsim 10^{-14}$ erg cm^{-2} s^{-1} (0.1–2.4 keV), contributing ~ 40 per cent of the total X-ray sources. We find 6 possible new members in NGC 6633, and 4 candidates in IC 4756; all require further observation to establish membership probability.

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A Systematic Investigation of the Mass Loss Mechanism in Dust Forming Long–period Variable Stars

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In order to investigate the relations between the mass loss from pulsating red giants and quantities which can be obtained from observations, we have explored the behavior of theoretical models which treat the time-dependent hydrodynamics of circumstellar outflows, including a detailed treatment of the dust formation process. This approach, while ignoring effects such as a possible non-sphericity of the stellar atmospheres which are difficult to assess, accounts correctly for factors such as the grain formation and destruction which are crucial to the mass-loss mechanism.

We built a grid of $\sim$ 150 models covering a wide range of physical situations. This grid allows us to characterize the effects of different parameters, such as the stellar luminosity and temperature, the period and the amplitude of the pulsation, and the C/O element abundance ratio, on the behavior of AGB winds and on the rates of mass loss.

We find two regimes for the stellar outflows. The first one (A) is characterized by stable winds with a layered structure of the circumstellar dust shell, outflow velocities in excess of $5\,\mathrm{km\,s^{-1}}$, and a large rate of mass loss. These outflows are dominated by radiation pressure on dust. For these models we find good correlations between near-infrared colors and the mass loss rates. In the second regime (B), the winds are slow and do not present a layered structure. The outflows displaying the second behavior come, e.g., from red giants with low luminosity, high temperature, or short period. For them there is no correlation between color and mass loss rate. The mass loss rates are low and never exceed $3\,10^{-7} M_{\odot}\mathrm{yr}^{-1}$. Radiation pressure on dust plays only a minor role in this regime.

We have explored the effect of different parameters on the behavior of the stellar winds. We find that, in general, all other parameters been kept identical, there is a narrow range of values for each parameter within which the models abruptly change from B to A, and that once a model is stabilized in the A mode the changes in the values of each parameter have only a smooth effect on the wind characteristics.

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X-ray Emission from Nearby M-dwarfs: the Super-Saturation Phenomenon

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A rotation rate and X-ray luminosity analysis is presented for rapidly rotating single and binary M-dwarf systems. X-ray luminosities for the majority of both single & binary M-dwarf systems with periods below $\simeq 5-6$ days (equatorial velocities, $\mathrm{V}_{eq} \gtrsim 6$ km s^{-1}) are consistent with the current rotation-activity paradigm, and appear to saturate at about 10^{-3} of the stellar bolometric luminosity.

The single M-dwarf data show tentative evidence for the super-saturation phenomenon observed in some ultra-fast rotating ($\gtrsim$100 km s^{-1}) G & K-dwarfs in the IC 2391, IC 2602 and Alpha Persei clusters. The IC 2391 M star VXR60b is the least X-ray active and most rapidly rotating of the short period ($\mathrm{P}_{rot} \lesssim 2$ days) stars considered herein, with a period of 0.212 days and an X-ray activity level about 1.5 sigma below the mean X-ray emission level for most of the single M-dwarf sample. For this star, and possibly one other, we cautiously believe that we have identified the first evidence of super-saturation in M-dwarfs. If we are wrong, we demonstrate that only M-dwarfs rotating close to their break up velocities are likely to exhibit the super-saturation effect at X-ray wavelengths.

The M-dwarf X-ray data also show that there is no evidence for any difference in the X-ray behaviour between the single and binary systems, because for the single stars, the mean log $L_{\mathrm{x}}/L_{\mathrm{bol}} = -3.21 \pm 0.04$ ($0.2 \lesssim \mathrm{P}_{rot} \lesssim 10.1$ days), whereas for the binary stars, the mean log $L_{\mathrm{x}}/L_{\mathrm{bol}} = -3.19 \pm 0.10$ ($0.8 \lesssim \mathrm{P}_{rot} \lesssim 10.4$ days).

Furthermore, we show that extremely X-ray active M-dwarfs exhibit a *blue excess* of about 0.1 magnitudes in U$-$B compared to less active field M-dwarfs. Such an excess level is comparable to that observed for extremely chromospherically active M-dwarfs. Moreover, as is the case for M-dwarf Ca II H & K activity levels, there is an *exclusion zone* of X-ray activity between the extremely active M-dwarfs and the less active ones.

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Solar Abstracts

Elusive Magnetic Structures in the Sun and Solar-Type Stars

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The magnetic structures of the Sun are very inhomogeneous, with irregularities smaller than the smallest sizes that we resolve from Earth. Such irregularities are not properly accounted for by standard magnetic field diagnostic techniques. We have identified a quantitatively important bias which has remained unnoticed hitherto. Intense magnetic fields embedded in inhomogeneous magnetic structures produce little light and easily escape detection. These elusive magnetic fields, which cheat standard observing techniques, seem to be common. We estimate that they carry at least half of the solar magnetic flux. Should the bias be so severe, it would cast doubts on the present interpretation of many solar magnetic phenomena. Since magnetic field measurements in solar-type stars reproduce solar methods, they are liable to the same systematic errors.

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On the Origin of Polar Radio Brightenings at Short Millimeter Wavelengths

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Polar regions of the Sun are areas where coronal holes are most profound and where the heating and acceleration of solar wind plasma takes place. The observed and yet unexplained radio emission from these regions may be related to the origin of the solar wind flow. The recent analysis of polar radio brightenings at 87 GHz (3.5 mm), and comparison to features seen in EUV (SOHO/EIT) and soft X-rays (Yohkoh/SXT) by Pohjolainen et al. (A&A Suppl. Ser., 2000, 143, 227), suggests structural counterparts like polar plumes, EUV and/or soft X-ray bright points, and diffuse EUV brightenings.

In this paper, radio brightness temperatures for these types of features are calculated by using the average temperature and density values from EUV and soft X-ray observations, assuming isothermal and optically thin plasma. The calculated values are in agreement with the observed ones. The calculations show some bright points and plume bases to be observable in mm-waves, but that the observability depends strongly on density and loop geometry of individual sources. Coronal holes in general should be seen as radio depressions at 87 GHz. It is suggested that the unexplained polar radio brightenings (i.e. when no counterpart is seen in EUV and/or soft X-rays) could be formed in a lower atmospheric layer and/or be related to magnetic flux elements.

Also a slight, 2.0% maximum, smooth limb brightening is found to affect the radio observations inside $0.6 - 0.92$ R_{sun}. This limb brightening is much less than reported earlier at the same wavelength, which suggests a slightly different chromospheric model.

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Spectrum and Proper Motion of a Brown Dwarf Companion of the T Tauri Star CoD−33°7795

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We present optical and infrared spectra as well as the proper motion of an H=12 mag object 2″ off the ~ 5 mag brighter spectroscopic binary star CoD−33°7795 (=TWA-5), a member of the TW Hya association of T Tauri stars at ~ 55 pc. It was suggested as companion candidate by Lowrance et al. (1999) and Webb et al. (1999), but neither a spectrum nor the proper motion of the faint object were available before. Our spectra taken with FORS2 and ISAAC at the ESO-VLT reveal that the companion candidate has spectral type M8.5 to M9. It shows strong Hα emission and weak Na I absorption, both indicative of a young age. The faint object is clearly detected and resolved in our optical and infrared images, with a FWHM of 0.18″ in the FORS2 image. The faint object's proper motion, based on two year epoch difference, is consistent with the proper motion of CoD−33°7795 by 5 Gaussian σ significance. From three different theoretical pre-main sequence models, we estimate the companion mass to be between ~ 15 and 40 $M_{\rm jup}$, assuming the distance and age of the primary. A slight offset between the VLT and HST images with an epoch difference of two years can be interpreted as orbital motion. The probability for chance alignment of such a late-type object that close to CoD−33°7795 with the correct proper motion is below $7 \cdot 10^{-9}$. Hence, the faint object is physically associated with CoD−33°7795, the 4th brown dwarf companion around a normal star confirmed by both spectrum and proper motion, the first around a pre-main sequence star.

Accepted by A&A Letters

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The Onset of Methane in L Dwarfs

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We have detected weak absorption features produced by the strong ν_3 methane band at 3.3 μm in two L dwarfs, 2MASSW J1507476-162738 and 2MASSI J0825196+211552, classified by Kirkpatrick et al. (2000) as spectral types L5 and L7.5 respectively. These absorptions occur in objects warmer than any in which methane previously has been detected, and mark the first appearance of methane in the ultracool star – to – brown dwarf spectral sequence.

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Ph.D. Thesis Abstract

Thin Magnetic Flux Tubes in the Convective Layer of Young, Fast Rotating Stars

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Ph.D dissertation directed by: Klaus Strassmeier

Ph.D degree awarded: May 2000

As an attempt to apply a solar flux tube evolution model to other stars, I study the dynamics of magnetic flux tubes in young stars with masses between 0.4 $M_\odot$ and 1.7 $M_\odot$. The rotation rates considered range from 0.25 $\Omega_\odot$ to 63 $\Omega_\odot$. The first part of this study is dedicated to the computation of stellar models at ages from shortly after the Hayashi phase down to the ZAMS, i.e. from the classical and weak-line T Tauri stars to the α-Persei stars. State-of-the-art treatment of the equation of state and of the opacities are included and compared with older versions. The selection of the stellar models for the numerical simulation of the flux-tube rise follow two main guidelines. Firstly, to allow direct comparisons between different masses in similar evolutionary stages, physical conditions are used to define four distinct evolutionary stages. Secondly, with regard to open stellar clusters, stellar models of identical age but rather different evolutionary stages are considered.

The second part is dedicated to the numerical simulation of individual magnetic flux tubes: The flux-tube evolution from their origin – the bottom of the outer convective layer – up to near-surface layers where they form stellar spots is studied. Two key parameters govern the emergence latitude of the flux tubes, the stellar rotation rate and the size of the radiative core. For all stars, except the extremely young ones, a direct correlation between the rotation rate and the emergence latitude is evident. An almost radial emergence path of the flux tube with equatorial flux emergence at rotation rates below $\Omega \leq 1\ \Omega_\odot$ is superseded with vertical flux-tube rise as the rotation rate increases to $\Omega \geq 25\ \Omega_\odot$. The dependence of the emergence latitude from the core-size of the star is not so pronounced, but still obvious. Small stellar cores increase the emergence latitude. In pre-main-sequence stars, the radiative cores are small in young, low-mass stars.

At very early evolutionary stages, when the central radiative zone is still quite small, a bimodal spot pattern is observed. I find magnetic flux emergence both at low latitudes as well as in the polar areas, if the rotation rate is close to $\Omega \approx 10\ \Omega_\odot$. Truly polar spots are only present in the very young stars, while high-latitude emergence is predicted in slightly more evolved pre-main-sequence and young main-sequence stars. Polar spots on these stars require an additional transport mechanism after magnetic flux emergence at the surface, probably meridional circulation or a poleward slip of the 'anchored' part of the flux tube.

In a first attempt to link the Doppler-imaging observations with the theory, I present a comparison of recent surface temperature maps of young stars with theoretical flux tube emergence patterns. The results are encouraging enough to deduce that a dynamo mechanism similar to our Sun is responsible for magnetic activity on other stars.

Thesis-related Publications: A&A 355, 1087

JOB OPENING

Postdoctoral Research Position

Hamburger Sternwarte (Germany)

At **Hamburger Sternwarte** a full-time postdoctoral research position (BAT IIa) is vacant in the group of Prof. Dr. D. Reimers (Director of Hamburger Sternwarte). The initial appointment is for 2 years, starting **January 1, 2001**. An extension of 2 years is possible. The position is open to persons holding a PhD in Physics or Astronomy.

In a collaboration with the group of Prof. Dr. T. Gehren (Universitäts-Sternwarte München), the postdoc will work on high-resolution spectra of metal-poor halo stars discovered in the Hamburg/ESO objective-prism survey (HES). The German astronomical community has access to all ESO facilities, including the VLT. Through international collaborations, our group also has access to Keck and Subaru.

Duties include support in obtaining moderate-resolution follow-up spectroscopy for HES metal-poor candidates at 4 m class telescopes such as the ESO 3.6 m, CTIO 4 m, KPNO 4 m and CFHT, including data-reduction and analysis. Further spectra will be obtained with the Siding Spring Observatory 2.3 m telescope, and 6dF at the UK Schmidt.

The ideal candidate will have experience in quantitative spectroscopy and the analysis of high-resolution spectra. He/she will have experience in observing with modern optical telescopes, and data reduction.

If necessary, help with accommodation, visa and work permits will be given.

Applications shall include a short CV, list of publications, offprints of the most important publications, and a statement on research interests. The University of Hamburg operates an equal opportunities employment policy.

Please send your application to:

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Closing date is **November 1, 2000.**

For further information, contact:

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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. 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), brown dwarfs, 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

`http://casa.colorado.edu/~skinners/coolnews.html .`