COOLNEWS

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Stellar Abstracts

Lithium and Rotation on the Subgiant Branch. I- Observations and Spectral Analysis

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We have obtained new high resolution spectroscopic observations of the lithium line at 6707.81 Å and derived lithium abundances ($A_{\rm Li}$) by spectral synthesis for a sample of about 120 F-, G- and K-type Population I subgiant stars. For each of these stars, high precision rotational velocity obtained with the CORAVEL spectrometer is available. We present the behavior of the lithium abundance as a function of effective temperature, which shows a sort of discontinuity around 5600K, somewhat later than the well known rotational discontinuity.

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Doppler Imaging of BD+22°4409 (LO Peg) Using Least Squares Deconvolution

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We present maximum entropy reconstructions of the rapidly rotating dwarf single star BD+22°4409 (LO Peg) from observations at the William Herschel Telescope in August 1993. Since this star is too faint to use the conventional single or 3-line Doppler Imaging methods, we make use of the novel method of Least Squares Deconvolution, which utilizes the large number of photospheric lines in an echelle spectrum, to produce a single, high S:N profile.

The starspot distributions from the image reconstructions show cool features at both high and low latitudes, in contradiction to recent theoretical predictions of the dynamo behaviour in rapidly rotating stars. Cross-correlation of the images from consecutive nights shows a good correlation from the small scale structures, but no evidence of surface differential rotation. From the cross-correlation of the high latitude spot we are able to reject the period of

9.22 h of Jeffries et al. (1994) in favour of their preferred period of 10.17 h, confirming the result of Robb & Cardinal (1995).

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The Carbon Star IRAS 15194-5115: Circumstellar CO Radio and FIR Rotational Lines

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We have modelled radio and far-infrared rotational lines of ^{12}CO and ^{13}CO obtained from the circumstellar envelope of the infrared-bright carbon star IRAS 15194-5115. Eleven rotational lines between J=1–0 and 21–20 and nine rotational lines between J=1–0 and 22–21 in the ground vibrational states of ^{12}CO and ^{13}CO, respectively, provide the observational constraints. A model of the circumstellar envelope with a constant mass-loss rate ($1\times10^{-5}\,M_\odot\,\mathrm{yr}^{-1}$) and ^{12}CO/^{13}CO-ratio (5.5) is consistent with our observed FIR and radio data, suggesting that the wind characteristics have not changed significantly over the past few thousand years. Thus, IRAS 15194-5115 appears to be a highly evolved AGB-star, but the carbon star properties combined with the inferred low ^{12}C/^{13}C-ratio make the evolutionary status of this star uncertain. It may have been a J-star for which the ^{12}C/^{13}C-ratio has remained low, or it may be a star of 5 to 8 solar masses, which has recently become a carbon star due to quenching of hot bottom burning. The dust properties or the relative amount of dust in the envelope appear to be different from those in the envelope of the well known carbon star IRC+10 216.

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The Potential Magnetic Field of AB Doradus: Comparison With Zeeman-Doppler Images.

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We have modelled the global magnetic field topology of the young, rapidly-rotating K0 dwarf AB Dor by assuming that the field is potential and using as a boundary condition Zeeman-Doppler images of the surface radial field obtained on three consecutive years. For each of the observed radial field distributions, we calculate the azimuthal component of the corresponding potential field. We then compare at each epoch (by means of cross-correlation) the potential and observed azimuthal field distributions and find that there is a good correlation for magnetic features at latitudes below 60°. Above this latitude, the potential field fails to reproduce the almost unidirectional band of azimuthal field that is observed and the correlation is correspondingly poor.

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Coronal Emission and Dynamo Saturation

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We show that the observed saturation of X-ray emission with increasing rotation rate in solar-type stars does not necessarily imply saturation of the underlying dynamo. This effect can be caused by the centrifugal stripping of the corona. As the stellar rotation rate is increased, centrifugal forces cause a rise in the pressure and density in the outer parts of the largest magnetic loops. This may explain the observed formation of large prominences close to the co-rotation radius where centrifugal forces begin to dominate over gravity. In order for these massive prominences to be contained against centrifugal ejection, the coronal magnetic field must be highly stressed and must be evolving on a timescale of a few days as determined by the observed prominence lifetime. We postulate that the co-rotation radius marks the position at which the corona becomes distorted by centrifugal forces. As the stellar rotation rate is increased, the co-rotation radius moves closer to the surface, reducing the extent of the "undisturbed" corona. We take as illustrative examples two simple field topologies and show that if the X-ray emission comes only from this undisturbed volume, then a saturation of the X-ray emission with increasing rotation rate occurs naturally. This effect may mimic true dynamo saturation or disguise its onset.

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Two–Component Theoretical Chromosphere Models for K Dwarfs of Different Magnetic Activity: Exploring the Ca II Emission — Stellar Rotation Relationship

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We compute two-component theoretical chromosphere models for K2 V stars with different levels of magnetic activity. The two components are: a non-magnetic component heated by acoustic waves, and a magnetic component heated by longitudinal tube waves. The filling factor for the magnetic component is determined from an observational relationship between the measured magnetic area coverage and the stellar rotation period. We consider stellar rotation periods between 10 d and 40 d. We investigate two different geometrical distributions of magnetic flux tubes: uniformly distributed tubes, and tubes arranged as a chromospheric network embedded in the nonmagnetic region. The chromosphere models are constructed by performing state-of-the-art calculations for the generation of acoustic and magnetic energy in stellar convection zones, the propagation and dissipation of this energy at the different atmospheric heights, and the formation of specific chromospheric emission lines which are then compared to the observational data. In all these steps, the two-component structure of stellar photospheres and chromospheres is fully taken into account. We find that heating and chromospheric emission is significantly increased in the magnetic component, and is strongest in flux tubes which spread the least with height, expected to occur on rapidly rotating stars with high magnetic filling factors. For stars with very slow rotation, we are able to reproduce the *basal flux limit* of chromospheric emission previously identified with non-magnetic regions. Most importantly, however, we find that the relationship between the Ca II H+K emission and the stellar rotation rate deduced from our models is consistent with the relationship given by observations. With the use of time-dependent two-component chromospheric (magneto-) acoustic heating models, it appears now also possible to directly link the $B_\mathrm{o} f_\mathrm{o} - P_\mathrm{rot}$ relationship to the $F_\mathrm{HK} - P_\mathrm{rot}$ relationship, which are both deduced from observations and are typical for a given type of stars.

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High Resolution Radio Observations of HM Sge. II Two Decades After Outburst

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HM Sge is a symbiotic binary star which underwent a nova-like outburst in 1975. Its radio emission has been monitored using MERLIN and the VLA, and maps from 1992 to 1997 are presented. Thermal emission within $0''.4$ of the optical

peak is elongated north-south and hot spots appear to be moving around an anti-clockwise ellipse. If this is due to motion in an inclined disc, the period is ~ 90 yr. Eyres et al. (1995) predicted that if this is due to Mach shocks in the post-nova wind, proper motions should be seen in expansion. This has not been detected since 1992 so an alternative model is adopted, based on Eyres et al. (1995) and Kenny (1997), of colliding winds in a binary system following the nova-like outburst. The emission peaks appear to be co-rotating with the binary orbit as the ionisation front and the hot wind from the white dwarf interact with the Mira wind. The positions of the stars are estimated, at a separation of ~ 25 au. A distance of ~ 1 kpc is most consistent with the observations reported here.

On arcsecond scales the emission is extended east-west consistent with a biconical outflow arising from the collimation of the nova outburst through interaction with the pre-existing cool wind. The presence of non-thermal emission at a separation of ~ 700 milli-arcseconds from the stars is confirmed. This is very unusual at such a distance from low-mass stars and could arise from synchrotron emission in a μT magnetic field. A model for this is developed which shows non-thermal emission is expected to decline within decades as the nova wind decelerates. This could explain the non-detection of non-thermal emission in other symbiotic stars.

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Maser Mapping of Small Scale Structure in the Circumstellar Envelope of S Persei

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Water and hydroxyl maser emission from the typical red supergiant star S Persei has been mapped using MERLIN. Water maser components are found grouped in clumps which appear to be discrete clouds with a velocity span of ~ 1 km s^{-1} and an angular size of ~ 8 milli-arcsec. This corresponds to a diameter of $(2.5 - 3)\times10^{12}$ m and is the first measurement of the unbeamed size of maser clouds. By comparing this with the full width half maximum (FWHM) beamed angular size, the beaming angle of the brightest partially saturated masers is $(1.5 \pm 0.8) \times 10^{-3}$ sr. Water maser cloud brightness temperatures are in the range $\sim 10^6$ to $> 10^{12}$ K. The water maser shell has well-defined inner and outer limits of $(8 - 26)\times10^{12}$ m. The quenching density at the inner rim shows that the water maser clouds are about 30 times denser than the average wind density in this region. This can be explained if $4 - 6$ dense dusty clouds (with a filling factor of $\sim 1/70$) are formed close to the photosphere during each stellar pulsation period of $2 - 3$ yrs.

The water masers show evidence for significant acceleration of the wind, and this continues with a shallower gradient into the hydroxyl regions at up to 9.3×10^{13} m. These results are consistent with a wind driven by radiation pressure on dust, but the ongoing acceleration implies that the dust surface absorption efficiency increases throughout the maser zones. Dust momentum is more efficiently coupled to the gas in the denser clouds, and the drift velocity is greater in less dense regions consistent with conditions (such as a longer velocity resonance length) required by 1612-MHz masers.

The circumstellar envelope appears to be spherical but irregularly filled. The milli-arcsec resolution at 22 GHz allows the radial distribution of maser brightness to be related to AAVSO light curves. An anomal ously dim region in the centre of the shell corresponds to low-amplitude periods in the 1930s; such behaviour is thought to reduce mass loss and dust formation efficiency.

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Stellar Coronal Abundances VI: The FIP Effect and ξ Boo A—Solar-like Anomalies at Intermediate Activity Levels

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Lines from different elements in the *Extreme Ultraviolet Explorer* (*EUVE*) spectra of the corona of the intermediate activity star ξ Boo A have been analysed. Assuming a photospheric composition for the plasma responsible for the observed coronal emission, emission measures derived from lines of elements with low first ionization potentials (FIPs) are systematically higher than emission measures derived from lines formed at similar temperatures but due to elements with high FIPs. This problem is alleviated by adopting a "coronal" abundance pattern similar to that which appears to characterize the average solar corona. We interpret these results as evidence that the same FIP-based compositional fractionation mechanism at work in the solar outer atmosphere is also operational in the coronae of significantly more active stars such as ξ Boo A.

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The Response of the EUVE Scanning and Deep Survey Telescopes to Coronal Plasma Radiative Loss

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Over half the sources detected in the Extreme Ultraviolet Explorer (EUVE) All-Sky and Deep surveys (50–760 Å) that have known optical counterparts are late-type stars. The EUV emission from late-type stars is thought to originate from hot, collisionally dominated, optically thin plasmas with temperatures ranging between 10^5 and 10^8 K, that are confined by magnetic structures analogous to those observed on ths Sun. The different filters providing wavelength discrimination used on the EUVE scanning telescopes are sensitive to emission from optically thin plasmas with temperatures throughout this range. We have investigated the responses of each of the EUVE photometric instruments as a function of plasma temperature for different interstellar medium column densities. The results will be of use for interpreting EUVE photometric count rates for astrophysical collisionally dominated optically thin plasma sources. The different sources of uncertainty entering into these types of calculation are reviewed. Three issues of special importance not generally considered in the the interpretation of EUV observations of radiative loss are emphasized: (i) current radiative loss models are incomplete in their treatment of ionization states with $n = 2$ and $n = 3$ ground states; (ii) the interstellar medium neutral and ionized He absorbing columns are generally unknown and represent potentially large uncertainties in the interpretation of EUV photometry; (iii) plasma chemical composition has a large influence on the shape of radiative loss curves, photometric flux calibrations and derived emission measures.

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Study of FK Comae Berenices. I. Surface images for 1994 and 1995

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We present new surface images of FK Com for August 1994 and July 1995. For the 1995 images two different inversion methods, Tikhonov regularization and the Occamian approach, are used to check the dependence on the formal assumptions. The images are found to be very similar when the same local line profiles, models, stellar parameters and observations are used as inputs for both methods. The validity of the maps and their temperature scales are independently checked with photometric observations.

The maps for both years show active regions of very similar substructures and latitudes. It seems that the same spot group has survived on the surface of FK Com for the 11 months between the observations; however, during that time it has moved about 0.2 in phase. The movement and evolution of the spot groups seem to cause the photometrically observed "flip-flop" phenomenon, which is noticed to be repeated with an average period of 6.5 years, similar to some RS CVn-stars.

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Techniques for Automated High-Precision Photometry of Sun-Like Stars

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Tennessee State University operates several Automatic Photoelectric Telescopes (APTs) located at Fairborn Observatory in the Patagonia Mountains of southern Arizona. The APTs are dedicated to photometric monitoring programs that would be difficult and expensive to accomplish without the advantages provided by automation. I describe the operation of two of the telescopes (a 0.75 m and a 0.80 m APT) and the quality-control techniques that result in their routine acquisition of single-star differential photometry with a precision of 0.001 mag for single observations and 0.0001–0.0002 mag for seasonal means. I show that a primary obstacle to high-precision photometry is intrinsic variability in the comparison stars. Finally, I illustrate the capabilities of the APTs with sample results from a program to measure luminosity cycles in Sun-like stars and a related effort to search for extrasolar planets around these stars.

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Solar Abstracts

Nonlinear Sunspot Transition Region Oscillations in NOAA 8378

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Observations obtained with the *Solar and Heliospheric Observatory - SOHO* joint observing program for velocity fields in sunspot regions are used to study the 3 minute transition region oscillations above four sunspots. Here we report mainly on the results obtained for NOAA 8378, based on simultaneous recordings of the transition region lines O v λ629, N v λ1238, λ1242 and the chromospheric Si ii λ1260 line with the SUMER instrument. The 3 minute transition region oscillations in NOAA 8378 occur mainly above the umbra and show 1) larger peak line intensity amplitudes than reported before, 2) clear signs of nonlinearities, 3) significant oscillations in line width, 4) maxima in peak line intensity and maxima in velocity directed towards the observer are nearly, but not exactly in phase, and 5) a clear connection to the oscillations in the sunspot chromosphere. The suggestion that the waves are upward-propagating acoustic waves is confronted with the observations by a simple test.

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Helioseismic Constraints on the Structure of the Solar Tachocline

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This paper presents a series of helioseismic inversions aimed at determining with the highest possible confidence and accuracy the structure of the rotational shear layer (the *tachocline*) located beneath the base of the solar convective envelope. We are particularly interested in identifying features of the inversions that are robust properties of the data, in the sense of not being overly influenced by the choice of analysis methods.

Towards this aim we carry out two types of two-dimensional linear inversions, namely Regularized Least-Squares (RLS) and Subtractive Optimally Localized Averages (SOLA), the latter formulated in terms of either the rotation rate or its radial gradient. We also perform nonlinear parametric least-squares fits using a genetic algorithm-based forward modeling technique. The sensitivity of each method is thoroughly tested on synthetic data.

The three methods are then used on the LOWL 2-year frequency splitting dataset. The tachocline is found to have an equatorial thickness of $w/R_\odot = 0.039 \pm 0.013$ and equatorial central radius $r_c/R_\odot = 0.693 \pm 0.002$. All three techniques also indicate that the tachocline is *prolate*, with a difference in central radius $\Delta r_c/R_\odot \simeq 0.024 \pm 0.004$ between latitude 60° and the equator. Assuming uncorrelated and normally distributed errors, a strictly spherical tachocline can be rejected at the 99% confidence level. No statistically significant variation in tachocline thickness with latitude is found. Implications of these results for hydrodynamical and magnetohydrodynamical models of the solar tachocline are discussed.

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Dynamics of the Solar Granulation – VI. Time Variation of the Granular Shear Flow

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Excellent spectrograms can yield observational insight in the dynamics of the solar surface not yet accessible to numerical simulations. We present results of the elaboration of a series of spectrograms taken at the center of the solar disk. Each of the spectrograms includes more than 250 granules, while the series covers a time of 12 min. Our main emphasis is to study the dynamics of the visible solar layers not only as a function of height but also as a function of time.

We investigated the temporal and spatial behavior of the turbulent concentration at the granular borders and its spreading-out into the intergranular space. In the deep photosphere, enhanced turbulence is concentrated predominantly near granular borders, while at higher layers the turbulence spreads out over the entire intergranular space. Remarkable is the decay of the turbulence with the height in the photosphere. There was no significant variation of the turbulence over the 12 min.

We also determined the rms turbulent pressure at the granulation layers near $\tau_{5000} = 1$. The average ratio of turbulent to gas pressure is of the order of 0.1; values of this size are also discussed in recent theoretical works. In order to take the intermittency into account, we traced the peak to peak variations of the turbulent velocity, which turn out to be ≈ 4 km sec^{-1}. The corresponding ratio of turbulent to gas pressure may thus reach locally significant values up to about 0.3.

We did not find either a correlation or an anticorrelation between turbulence and convective flow, although the turbulence is presumably generated by granular shear flow. We suggest that the intermittent turbulence in the visible layers and the convective flow constitutes a dynamical system. This *turbulence–granulation*–dynamical system exhibits a cyclic behavior corresponding to the *dynamical* time of the granules, i.e. the growth and decay of their velocity profile.

The power spectra of the turbulent and granular velocity show a two-component character, which presumably reflects the action of two different processes determining the dynamics of the solar convective boundary layers and above.

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On Photospheric Fluorescence and the Nature of the 17.62 Å Feature in Solar X-ray

Spectra

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The identification of the emission line feature at 17.62 Å in solar X-ray spectra is re-examined. Using a Monte Carlo technique, we compute a realistic theoretical upper limit to the observed Fe Lα photospheric fluorescent line strength caused by irradiation from an overlying corona. These calculations demonstrate that the photospheric Fe Lα characteristic line is much too weak to account for the observed 17.62 Å line flux. Instead, we identify this line with the configuration interaction $2s^22p^43p\ ^2\mathrm{P}_{3/2}$–$2s2p^6\ ^2\mathrm{S}_{1/2}$ transition in Fe XVIII seen in Electron Beam Ion Trap spectra and predicted in earlier theoretical work on the Fe XVIII X-ray spectrum. This line should be easily resolved and detected in stellar coronae by the spectrographs on the upcoming CXO and XMM missions.

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Non–Equilibrium Ionization and the Interpretation of Yohkoh/SXT Data During Solar Dynamic Events

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Yohkoh has been dedicated to study the structure and evolution of the solar corona, especially during dynamic events. During such events, however, the collisional equilibrium ionization – which is invariably assumed when deriving the plasma parameters from the observations – may not apply. We explore the influence of the non–equilibrium ionization effects (NEI) on the values of temperature and emission measure derived from the data collected with the Solar X–ray Telescope (SXT) on board the Yohkoh satellite during solar dynamic events. To this end, we have simulated such dynamic events, assuming that the plasma temperature rises instantaneously from the value T_0 to the value T_1, and then it remains constant. We have considered two different temperature jumps: the first one from $10^{6.3}$ K to $10^{7.3}$ K to simulate a flare and the other, from $10^{5.7}$ K to $10^{6.5}$ K, to simulate a microflare.

We show that the temperature determination with the SXT wide band filter ratio is, to some extent, affected by non–equilibrium ionization: the maximum fractional error on T_1 amounts to ~ 0.7 for the flare and ~ 0.5 for the microflare we have simulated. On the other hand, the emission measure determination can be considerably affected by such departures: the maximum fractional error on EM amounts to ~ 2 for the flare and ~ 7 for the microflare we have simulated. Therefore NEI effects can be important on the temperature and emission measure determination during fast evolving phenomena.

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The Sun as an X–ray Star I: Deriving the Emission Measure Distribution vs. Temperature of the Whole Solar Corona from the Yohkoh/SXT Data

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The scope of this work is to obtain the emission measure distributions vs. temperature, EM(T), of the whole solar corona from Yohkoh/SXT images. As discussed in Paper II, the EM(T) is our starting point to study the Sun as an

X–ray star. To this purpose, we need to extract as much information as possible from the Yohkoh/SXT data covering the whole range of the Yohkoh/SXT temperature sensitivity, i.e. $5.5 < \log T(\mathrm{K}) < 8$. In particular, at low photon counts and temperatures below 10^6 K, errors on the temperature and emission measure determination are expected to be large. To this end we have made an extensive set of simulations to explore the nominal performance of the entire system (instrument and data analysis system) in the determination of the plasma temperature and emission measure at low, intermediate and high photon counts per pixel. We have shown that low–count data with a number of photons per pixel $n_{\rm phot} < 10$ are affected by large errors and lead to the derivation of an unrealistic EM(T) characterized by a steep negative slope. As a result, we have devised an analysis method which minimizes the instrumental and statistical effects on the determination of EM(T) and allows us to determine the global coronal EM(T). As a first application to real SXT data, we have derived the EM(T) of the Sun close to the maximum of the solar cycle, a challenging case. The low temperature part is in agreement with analogous studies made in the UV band and it shows a well defined maximum at $T \sim 2$ MK.

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Brown Dwarf Abstracts

Revised Fluxes for Gliese 229B

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We have used the coronographic instrument CoCo with the IRTF's facility camera NSFCAM to obtain improved photometry at JHKL′ of the giant planet/brown dwarf Gliese 229B. We have recalibrated the published spectra for this object, and re–calculated its luminosity. Our L′ value, and our flux calibration of the spectra at JHK, are significantly different from those previously published. Our results show good agreement at all bands except H with evolutionary models by Burrows et al. which include grain condensation. The model comparison implies that Gliese 229B is likely to be a 0.5 Gyr–old 25 M_J object with T_{eff} ∼900 K.

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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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