COOLNEWS

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Stellar Abstracts

Doppler Imaging of Stellar Surface Structure. XX. The Rapidly-rotating Single K2-giant HD 31993 = V1192 Orionis

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We present two Doppler images from two consecutive stellar rotations of the single K2-giant HD 31993. Each Doppler image is reconstructed from spectra obtained within a single stellar rotation. With its 25-day rotational period and a radius of $\approx$18 solar radii, HD 31993 is considered a very rapidly rotating star and thus allows the application of the Doppler-imaging technique, despite the unusually long period. All maps reveal 7 isolated, predominantly low-latitude spots with a temperature difference, photosphere minus spot, of just $\approx$200 K. No polar spot or high-latitude activity above, say, $+60^\circ$ is seen. A large warm feature is detected at high latitude and is believed to be real. These spots act as tracers for a cross correlation analysis and yield a clear signature of anti-solar differential surface rotation, i.e. the polar regions rotating faster than the equator, with α=0.125$\pm$0.05 corresponding to a lap time of $\approx$200 days. A detailed parameter study is carried out to verify the reality of the HD 31993 maps.

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On the Link Between Rotation, Chromospheric Activity and Li Abundance in Subgiant Stars

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The connection rotation–CaII emission flux–lithium abundance is analyzed for a sample of bona fide subgiant stars, with evolutionary status determined from HIPPARCOS trigonometric parallax measurements and from the Toulouse–Geneva code. The distribution of rotation and CaII emission flux as a function of effective temperature shows a discontinuity located rather around the same spectral type, F8IV. Blueward of this spectral type subgiants have a large spread of values of rotation and CaII flux, whereas stars redward of F8IV show essentially low rotation and low CaII flux. The strength of these declines depends clearly on stellar mass. The abundance of lithium also shows a sudden decrease. For subgiants with mass lower than about 1.2 $M_\odot$ the decrease is located later than that in rotation and CaII flux, whereas for masses higher than 1.2 $M_\odot$ the decrease in lithium abundance is located around the spectral type F8IV.

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Observational Constraints for Lithium Depletion Before the RGB

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Precise Li abundances are determined for 54 giant stars mostly evolving across the Hertzsprung gap. We combine these data with rotational velocity and with information related to the deepening of the convective zone of the stars to analyse their link to Li dilution in the referred spectral region. A sudden decline in Li abundance paralleling the one already established in rotation is quite clear. Following similar results for other stellar luminosity classes and spectral regions, there is no linear relation between Li abundance and rotation, in spite of the fact that most of the fast rotators present high Li content. The effects of convection in driving the Li dilution is also quite clear. Stars with high Li content are mostly those with an undeveloped convective zone, whereas stars with a developed convective zone present clear sign of Li dilution.

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Mass-loss from Dusty, Low Outflow-velocity AGB Stars I. Wind Structure and Mass-loss Rates

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We present the first results of a CO(2-1), (1-0), and 86 GHz SiO maser survey of AGB stars, selected by their weak near-infrared excess. Among the 65 sources of the present sample we find 10 objects with low CO outflow velocities, $v_{\rm exp} \leq 5\,{\rm km\,s^{-1}}$. Typically, these sources show (much) wider SiO maser features. Additionally, we get 5 sources with composite CO line profiles, i.e. a narrow feature is superimposed on a broader one, where both components are centered at the same stellar velocity. The gas mass-loss rates, outflow velocities and velocity structures suggested by these line profiles are compared with the results of hydrodynamical model calculations for dust forming molecular winds of pulsating AGB stars. The observations presented here give support to our recent low outflow-velocity models, in which only small amounts of dust are formed. Therefore, the wind generation in these models is dominated by stellar pulsation. We interpret the composite line profiles in terms of successive winds with different characteristics. Our hydrodynamical models, which show that the wind properties may be extremely sensitive to the stellar parameters, support such a scenario.

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Confirmation of Solar-like Oscillations in Eta Bootis

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We obtained time-series spectroscopy of the G0 subgiant η Boo in an attempt to confirm the solar-like oscillations reported by Kjeldsen et al. (1995). We recorded 1843 spectra over six consecutive nights with the Nordic Optical Telescope, which we used to measure equivalent widths of strong temperature-sensitive lines. We also measured velocities from 1989 spectra obtained through an iodine reference cell at Lick Observatory over 56 nights that were badly affected by weather. Our analysis also included velocity measurements published by Brown et al. (1997) and the original equivalent-width measurements by Kjeldsen et al. (1995). All four data sets show power excesses consistent with oscillations, although with a range of amplitudes that presumably reflects the stochastic nature of the excitation. The highest peaks show regularity with a large separation of $\Delta\nu = 40.4\,\mu$Hz and we identify 21 oscillation frequencies from the combined data.

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X-ray Evidence of the Common Envelope Phase of V471 Tauri

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Chandra Low Energy Transmission Grating Spectrograph observations of the pre-cataclysmic binary V471 Tau have been used to estimate the C/N abundance ratio of the K dwarf component for the first time. While the white dwarf component dominates the spectrum longward of 50 Å, at shorter wavelengths the observed X-ray emission is entirely due to coronal emission from the K dwarf. The H-like 2p $^2P_{3/2,1/2} \rightarrow$ 1s $^2S_{1/2}$ resonance lines of C and N yield an estimate of their logarithmic abundance ratio relative to the Sun of [C/N]$= -0.38 \pm 0.15$—half of the currently accepted solar value. We interpret this result as the first clear observational evidence for the presumed common envelope phase of this system, during which the surface of the K dwarf was contaminated by CN-cycle processed material dredged up into the red giant envelope. We use the measured C/N ratio to deduce that 0.015-0.04 $M_\odot$ was accreted by the K dwarf while engulfed, and show that this is consistent with a recent tentative detection of ^{13}C in the K dwarf photosphere, and with the measured Li abundance in the scenario where the red giant companion was Li-rich during the common envelope phase.

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The Extreme-Ultraviolet Continuum of a Strong Stellar Flare

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We present the serendipitous detection of an extreme ultraviolet flare on EUVE J0613−23.9B. The flare showed over a 200-fold increase above the quiescent emission in the DS/Lexan 60–200Å wavelength band. Optical spectroscopy revealed that the event was associated with an active dM3.5e star. The EUVE spectra are dominated by emission lines formed at temperatures in excess of 10^7 K. The observation is unique as we have detected, for the first time, a strong Lyman continuum in the EUVE long wavelength range (320 − 650Å). The flare in the continuum (T≈ $20,000 - 30,000$ K) was extremely short, lasting for less than 500 sec while in the DS (T≈ 10^7 K) its duration was ≈ 28ksec. The total energy of the flare in the DS is ∼3x10^{34} ergs. We have made a fit to the continuum using semiempirical model atmospheres and derived the time average temperature and density structures.

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Buried Alive in the Coronal Graveyard

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We have used the High Resolution Camera (HRC-I) of the *Chandra* X-ray Observatory to search for coronal ($T \sim 10^6$ K) emission from the archetype "noncoronal" red giants Arcturus (α Boötis; HD124897: K1 III) and Aldebaran (α Tauri; HD29139: K5 III). Our program follows up previous detections of ultraviolet coronal proxies such as C IV $\lambda1548$ ($T \sim 1 \times 10^5$ K) and O VI $\lambda1031$ ($T \sim 3 \times 10^5$ K). The deep ($\sim$ 19 ks) HRC-I pointings obtained a tentative $3\,\sigma$ detection of Arcturus, with $f_{\rm X}(0.2\text{–}2~{\rm keV}) = 1.0^{+1.8}_{-0.8} \times 10^{-15}$ ergs cm^{-2} s^{-1} (95% confidence limits [CL]), but failed to record Aldebaran, with an upper limit of $< 1.5 \times 10^{-15}$ ergs cm^{-2} s^{-1} (also at 95% CL). The corresponding $L_{\rm X}/L_{\rm bol}$ ratios are a factor of *ten thousand* less than the Sun, a low-activity coronal dwarf. At the same time, *HST* STIS far-ultraviolet spectra suggest the presence of a "cool absorber," probably near the base of the red giant chromosphere, imprinting discrete low-excitation absorptions on top of highly ionized features such as Si IV $\lambda1393$. The hot emission zones thus are at least partially buried under a large column of chromospheric material, which would severely attenuate any soft X-rays that might be emitted. The submerged hot structures presumably are magnetic owing to their high temperatures and broad C IV profiles (FWHM∼ 130 km s^{-1}). Perhaps these structures are analogous to small-scale ephemeral bipolar regions seen ubiquitously on the Sun throughout the sunspot cycle, and thought to be of direct convective origin. If small-scale magnetic fields indeed are present in the lower atmospheres of red giants like Arcturus and Aldebaran, they might play a role in initiating the cool winds of such stars, perhaps through a mechanism similar to solar spicules.

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Kinetic Equilibrium of Iron in the Atmospheres of Cool Stars III. The Ionization Equilibrium of Selected Reference Stars

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Non-LTE line formation calculations of Fe I are performed for a small number of reference stars to investigate and

quantify the efficiency of neutral hydrogen collisions. Using the atomic model that was described in previous publications, the final discrimination with respect to hydrogen collisions is based on the condition that the surface gravities as determined by the Fe I/Fe II ionization equilibria are in agreement with their astrometric counterparts obtained from HIPPARCOS parallaxes. Depending on the choice of the hydrogen collision scaling factor $S_{\rm H}$, we find deviations from LTE in Fe I ranging from 0.00 ($S_{\rm H} = \infty$) to 0.46 dex ($S_{\rm H} = 0$ for HD140283) in the logarithmic abundances while Fe II follows LTE.

With the exception of Procyon, for which a mild temperature correction is needed to fulfil the ionization balance, excellent consistency is obtained for the metal-poor reference stars if Balmer profile temperatures are combined with $S_{\rm H} = 3$. The correct choice of collisional damping parameters ("van-der-Waals" constants) is found to be generally more important for these little evolved metal-poor stars than considering departures from LTE. For the Sun the calibrated value for $S_{\rm H}$ leads to average Fe I non-LTE corrections of 0.02 dex and a mean abundance from Fe I lines of $\log \varepsilon({\rm Fe}) = 7.49 \pm 0.08$. We confront the deduced stellar parameters with comparable spectroscopic analyses by other authors which also rely on the iron ionization equilibrium as a gravity indicator. On the basis of the HIPPARCOS astrometry our results are shown to be an order of magnitude more precise than published data sets, both in terms of offset and star-to-star scatter.

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Acoustic Heating Models for the Basal Flux Star τ Ceti Including Time-dependent Ionization: Results for Ca II and Mg II Emission

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We present new calculations of chromospheric heating for τ Ceti (G8 V), a star exhibiting an extremely low level of chromospheric activity, thus also referred to as *basal flux star* or *flat activity star*. Our simulations consider energy deposition by acoustic shocks, and also take into account time-dependent (i.e., non-instantaneous) ionization processes of hydrogen, magnesium, and calcium allowing us to attain a new generation of chromospheric heating models previously obtained for the Sun. We consider both monochromatic waves and acoustic frequency spectra. The latter are calculated using new models of acoustic energy generation based on an extended Kolmogorov spectrum with a modified Gaussian frequency factor. Our models show that the theoretically deduced emergent Ca II and Mg II emission very much agree with observations adding to the argument that the chromospheres of basal flux stars are predominantly heated by acoustic shocks.

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Temporal Fluctuations in the Differential Rotation of Cool Active Stars

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This paper reports positive detections of surface differential rotation on two rapidly rotating cool stars at several epochs, by using stellar surface features (both cool spots and magnetic regions) as tracers of the large scale latitudinal shear that distorts the convective envelope in this type of stars. We also report definite evidence that this differential rotation is different when estimated from cool spots or magnetic regions, and that it undergoes temporal fluctuations of potentially large amplitude on a time scale of a few years.

We consider these results as further evidence that the dynamo processes operating in these stars are distributed throughout the convective zone rather than being confined at its base as in the Sun. By comparing our observations with two very simple models of the differential rotation within the convective zone, we obtain evidence that the internal rotation velocity field of the stars we investigated is not like that of the Sun, and may resemble that we expect for

rapid rotators. We speculate that the changes in differential rotation result from the dynamo processes (and from the underlying magnetic cycle) that periodically converts magnetic energy into kinetic energy and vice versa.

We emphasise that the technique outlined in this paper corresponds to the first practical method for investigating the large scale rotation velocity field within convective zones of cool active stars, and offers several advantages over asteroseismology for this particular purpose and this specific stellar class.

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Dynamo Processes and Activity Cycles of the Active Stars AB Doradus, LQ Hydrae and HR 1099

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We present in this paper new brightness and magnetic surface images of the young K0 dwarfs AB Doradus and LQ Hydrae, and of the K1 subgiant of the RS CVn system HR 1099 (=V711 Tauri), reconstructed from Zeeman-Doppler imaging spectropolarimetric observations collected at the Anglo-Australian Telescope during five observing campaigns (totaling 50 nights), from 1998 January to 2002 January. Along with the older images of the same stars (published in previous papers), our complete data set represents the first long term series on temporal fluctuations of magnetic topologies of very active stars.

All magnetic images presented here indicate that large regions with predominantly azimuthal magnetic fields are continuously present at the surfaces of these stars. We take this as further evidence that the underlying dynamo processes that produce them are likely distributed throughout the entire convective zone (and not confined at its base as in the Sun). We speculate that the radial and azimuthal field maps that we recover correspond respectively to the poloidal and toroidal components of the large-scale dynamo field.

We find in particular that some signatures, for instance the relative fraction of magnetic energy stored in the large-scale poloidal and toroidal field components, as well as the polarity of the axisymmetric component of the field, are variable with time, and provide potentially fruitful diagnostics to investigate magnetic cycles in active stars other than the Sun. We report here the detection of partial polarity switches in some of the axisymmetric field components of two of our program stars (AB Dor and LQ Hya), suggesting that the dynamo operating in these stars may be cyclic.

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The Chemical Evolution of Magnesium Isotopic Abundances in the Solar Neighbourhood

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The abundance of the neutron-rich magnesium isotopes observed in metal-poor stars is explained quantitatively with a chemical evolution model of the local Galaxy that considers—for the first time—the metallicity-dependent contribution from intermediate mass stars. Previous models that simulate the variation of Mg isotopic ratios with metallicity in the solar neighbourhood have attributed the production of ^{25}Mg and ^{26}Mg exclusively to hydrostatic burning in massive stars. These models match the data well for [Fe/H] > -1.0 but severely underestimate ^{25,26}Mg/^{24}Mg at lower metallicities. Earlier studies have noted that this discrepancy may indicate a significant role played by intermediate mass stars. Only recently have detailed calculations of intermediate mass stellar yields of ^{25}Mg/^{24}Mg and ^{26}Mg/^{24}Mg become available with which to test this hypothesis. In an extension of previous work, we present a model that successfully matches the Mg isotopic abundances in nearby Galactic disk stars through the incorporation of nucleosynthesis predictions of Mg isotopic production in asymptotic giant branch stars.

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Solar Abstracts

Families of Fragmenting Granules and Their Relation to Meso– and Supergranular Flow Fields

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3D analysis (x, y, t) of the granular intensity field (11–hour time sequence from the Swedish Vacuum Solar Telescope on La Palma, Canary Islands), demonstrates that a significant fraction of the granules in the photosphere are organized in the form of "Trees of Fragmenting Granules" (TFGs). A TFG consists of a family of repeatedly splitting granules, originating from a single granule at its beginning. A striking result is that TFGs can live much longer (up to 8 h) than individual granules (10 min). We find that 62 % of the area covered by granules belongs to TFGs of a lifetime > 1.5 h.

When averaged in time, such long–lived TFGs correspond to coherent diverging flows which may be identified as mesogranules. We also find a correlation between the network and the spatial distribution of TFGs.

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Low-Mass and Substellar Abstracts

The 2MASS Wide-Field T Dwarf Search. II. Discovery of Three T Dwarfs in the Southern Hemisphere

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We present the discovery of three new Southern Hemisphere T dwarfs identified in the Two Micron All Sky Survey. These objects, 2MASS 0348−6022, 2MASS 0516−0445, and 2MASS 2228−4310, have classifications T7, T5.5, and

T6.5, respectively. Using linear absolute magnitude/spectral type relations derived from T dwarfs with measured parallaxes, we estimate spectrophotometric distances for these discoveries; the closest, 2MASS 0348−6022, is likely within 10 pc of the Sun. Proper motions and estimated tangential velocities are consistent with membership in the Galactic disk population. We also list Southern Hemisphere T dwarf candidates that were either not found in subsequent near-infrared imaging observations and are most likely uncatalogued minor planets, or have near-infrared spectra consistent with background stars.

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The ELODIE Survey for Northern Extra-Solar Planets I. 6 New Extra-Solar Planet Candidates

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Precise radial–velocity observations at Haute–Provence Observatory (OHP, France) with the ELODIE echelle spectrograph have been undertaken since 1994. In addition to several discoveries described elsewhere, including and following that of 51 Peg b, they reveal new sub–stellar companions with essentially moderate to long periods. We report here about such

companions orbiting five solar–type stars (HD 8574, HD 23596, HD 33636, HD 50554, HD 106252) and one sub–giant star (HD 190228). The companion of HD 8574 has an intermediate period of 227.55 days and a semi–major axis of 0.77 AU. All other companions have long periods, exceeding 3 years, and consequently their semi–major axes are around or above 2 AU. The detected companions have minimum masses $m_2 \sin i$ ranging from slightly more than $2\,\mathrm{M_{Jup}}$ to $10.6\,\mathrm{M_{Jup}}$. These additional objects reinforce the conclusion that most planetary companions have masses lower than $5\,\mathrm{M_{Jup}}$ but with a tail of the mass distribution going up above $15\,\mathrm{M_{Jup}}$. The orbits are all eccentric and 4 out of 6 have an eccentricity of the order of 0.5. Four stars exhibit solar metallicity, one is metal–rich and one metal–poor. With 6 new extra–solar planet candidates discovered, increasing their total known to–date number to 117, the *ELODIE Survey for Northern Extra-Solar Planets* yield is currently 18. We emphasize that 3 out of the 6 companions could in principle be resolved by diffraction–limited imaging on 8 m–class telescopes depending on the achievable contrast, and therefore be primary targets for first attempts of extra–solar planet direct imaging.

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The ELODIE Survey for Northern Extra-Solar Planets II. A Jovian Planet on a Long-Period Orbit Around GJ 777 A

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We present radial-velocity measurements obtained with the ELODIE and AFOE spectrographs for GJ 777 A (HD 190360), a metal-rich ([Fe/H] = 0.25) nearby ($d = 15.9$ pc) star in a stellar binary system. A long-period low radial-velocity amplitude variation is detected revealing the presence of a Jovian planetary companion. Some of the orbital elements remain weakly constrained because of the smallness of the signal compared to our instrumental precision. The detailed orbital shape is therefore not well established. We present our best fitted orbital solution: an eccentric ($e = 0.48$) 10.7–year orbit. The minimum mass of the companion is $1.33\,\mathrm{M_{Jup}}$.

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The ELODIE Survey for Northern Extra-Solar Planets III. 3 Planetary Candidates Detected with ELODIE

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We present our ELODIE radial-velocity measurements of HD 74156 and 14 Her (HD 145675). These stars exhibit low-amplitude radial-velocity variations induced by the presence of planetary companions. The radial-velocity data of HD 74156 reveal the presence of two planetary companions: a 1.86 M_{Jup} planet on a 51.64–d orbit and a 6.4 M_{Jup} planet on a long-period ($\simeq 5.5$ yr) orbit. Both orbits are fairly eccentric ($e = 0.635$ and 0.56). The 4.8 M_{Jup} companion to HD 145675 has a long period (4.9 yr) and a moderately eccentric orbit ($e = 0.34$). We detect an additional linear radial-velocity trend superimposed to the periodic signal for this star. We also compute updated orbital solutions for HD 209458 and 51 Peg (HD 217014). Finally, we present our ELODIE radial-velocity data and orbital solutions for 5 stars known to host planetary companions: Ups And (HD 9826), 55 Cnc (HD 75732), 47 UMa (HD 95128), 70 Vir (HD 117176) and HD 187123. We confirm the previously published orbital solutions for Ups And, 70 Vir and HD 187123. Our data is not sufficient for fully confirming the orbital solutions for 55 Cnc and 47 UMa.

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Ph.D. Thesis Abstracts

Multi-Dimensional Radiation Hydrodynamic Simulations of the Non-Magnetic Solar Atmosphere

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After decades of intense research, still many details of the non-magnetic chromosphere of the Sun remain open. Observations of different spectral features lead to apparently contradicting models. On the one hand, observations in the UV (e.g., Ca II H+K) imply the existence of a thermal minimum at the bottom of the chromosphere and a strong temperature increase in the layers above but, on the other, the existence of carbon monoxide requires low temperatures at the same heights. Hence, it has been impossible to reproduce all diagnostics with a single comprehensive model so far – although many aspects can be modelled successfully if taken alone. Furthermore, the question arises how the high temperatures are generated which are demanded by various observations – though not by all of them. Next to magnetic effects, which are important for the higher layers, the non-magnetic regions of the lower atmospheric strata might be heated by acoustic waves. It is commonly assumed that such waves are excited by strong flows at the upper boundary of the convection zone.

In this thesis, the above indicated questions are addressed with three-dimensional radiation hydrodynamic simulations which comprise all strata which are relevant for the generation, propagation, and dissipation of acoustic waves and shocks, respectively. The computer code CO^{5}BOLD is used, which was recently developed by B. Freytag and M. Steffen. Magnetic fields are not taken into account, restricting the modelling in this thesis to so-called internetwork regions, i.e., areas with negligibly weak magnetic fields.
CO^{5}BOLD allows the time-dependent solution of the equations of radiative transfer and hydrodynamics for a fully compressible gas on a grid of Cartesian geometry in two or three spatial dimensions. Extensive computations finally produced a three-dimensional hydrodynamic reference model and additional two- and three-dimensional models with different parameters which were analysed with respect to the posed questions.
The most remarkable result is the structure of the model chromosphere which is highly variable in space and time. This already becomes clear from horizontal cuts through the reference model, which reveal network-like structures of hot gas with enclosed cool regions with temperatures down to $\sim$ 1800 K. The model chromosphere is thus characterised by a thermal bifurcation, i.e., the co-existence of hot and cool regions. While the spatial scales correspond to those of the granulation at the bottom of the photosphere, the time scales are much shorter in the chromosphere than in the layers below, roughly only of the order of $\sim$ 20 seconds.
The appearance of the chromosphere is a direct consequence of the interactions of propagating shock waves. The model shows clearly the continuous generation of waves near the upper boundary of the convection zone and the propagation of the waves into the thin upper atmospheric layers. Typically, the waves steepen into shocks in the low chromosphere, exhibiting large temperature and velocity amplitudes.
Dynamics are not only present in the form of propagating waves, but also as standing ('plane-parallel') oscillations, which affect the stratification as a whole. Height-dependent Fourier spectra, derived on the basis of averaged vertical velocities, clearly show a dominating oscillation mode with a period near five minutes. The contribution of the 5 min band to the total power decreases significantly in the higher layers, so that the power of the 3 min band dominates in the middle chromosphere. The corresponding oscillations of short period are rather unimportant in the lower layers. The modes and their variation with height is qualitatively in line with results inferred from observations. Thus, the dynamics of the solar atmosphere can be reproduced reasonably well.
In view of the high temporal and spatial variability and the connected large velocity and temperature variations it becomes clear that commonly used one-dimensional static models cannot provide a proper description of the outer atmosphere of the Sun. This is in particular true for the temperature stratification, which – in "classical" semi-empirical models features a temperature minimum and a rise in the layers above. The mean gas temperature of the three-dimensional reference model, however, exhibits only a weak, hardly notable minimum and an almost constant level above. This has already been found in one-dimensional dynamic simulations by Carlsson & Stein who also showed that the temperature rise in semi-empirical models is caused by the non-linear temperature dependence of the UV Planck function. Thus, mean UV intensities are governed by high temperatures, as present in shocks, so that inferred temperature stratifications might be misleading, in the sense that they do not represent the average gas temperature. This finding is confirmed by the mean emissivity temperature for the 3-D reference model presented here, indicating the essential importance of taking into account the spatial and temporal inhomogeneities.
Inspired by the very low temperatures, first time-dependent calculations for the formation of carbon monoxide molecules (CO) were performed. Despite strong simplifications the calculations show that CO can build up a significant concentration in the photosphere and low chromosphere, whereas it is effectively suppressed in the layers above – due to the presence of shock waves and the connected large temperature variations. Corresponding static calculations produce significantly higher concentrations, implying the need for a time-dependent approach.
Last but not least, the acoustic heating of the non-magnetic chromosphere is addressed. The conservation properties of CO^{5}BOLD allow a quantitative analysis of the energy fluxes and their divergence in the upper atmospheric layers. The 3-D reference model provides sufficient acoustic flux to account for the observed chromospheric emission – without need of additional contributions related to magnetic fields.
Some results depend on particular model assumptions to some extent, such as the amount of acoustic heating and the temperature amplitudes in the upper layers. In contrast, the lower part of the three-dimensional model remains mostly unaffected. In particular the spatial and temporal scales and the simulated dynamics are very robust with respect to changes of numerical details. Hence, in this thesis well-founded statements on the spatial and temporal inhomogeneities of the chromosphere can be made, which are obviously of great importance for the interpretation of observations and thus for the construction of a comprehensive model of the outer non-magnetic layers of the Sun.

Thesis-related Publications: AN 324, No.4, 410

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