COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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The Long-period RS CVn Binary IM Pegasi. II. First Surface Images

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New high-resolution, high signal-to-noise ratio spectroscopic observations and UBV photometry carried out in 1996-1999 are analysed with the surface imaging technique. A total of 8 images of IM Peg is obtained for the first time. A huge high-latitude active region is found to dominate the stellar surface; it was decreasing in area during the period of the observations. At the same time, on the opposite hemisphere (in longitude), smaller spots were developing. The spots were migrating in the orbital reference frame, the period of spot rotation being of 24.73±0.02 days. The spots constitute two active longitudes on opposite stellar hemispheres, similarly to other RS CVn stars. The evolution of the spot areas within the active longitudes indicates a stellar activity cycle, during which one active longitude dominates the stellar activity, to be about 6.5 years. Then, a total cycle, comprising two consecutive periods of activity of both active longitudes, is about 13 years. In 1999, the activity has switched to the other active longitude. This has declared the beginning of a new (half-) cycle.

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VLA Observation of dMe Stars

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We present new VLA radio observations of a sample of dMe stars in X, U, K, and Q bands (from 8.4 to 43 GHz) obtained during an observing campaign in 1996 April-June. The aim of the project was to determine the spectral energy distributions of late-type dwarf flare stars to investigate the possible existence of an inversion of the spectrum slope at frequencies higher than 8 GHz. We also tried to constrain the possible emission mechanism at radio frequencies. We have detections in X band (8.4 GHz), for three sources (UV Cet, V 1054 Oph, and EV Lac), while all of our other measurements are upper limits. We discuss how the weak radio emission of some sources (e.g. AU Mic) and the coronal plasma properties deduced from X-ray observations constrain the coronal magnetic field properties.

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The Nature of the Lithium Rich Giants - Mixing Episodes On the RGB and early-AGB

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We present a critical analysis of the nature of the so-called Li-rich RGB stars. For a majority of the stars, we have used Hipparcos parallaxes to determine masses and evolutionary states by comparing their position on the Hertzsprung-Russell diagram with theoretical evolutionary tracks. Among the twenty Li-rich giants whose location on the HR diagram we were able to determine precisely, eight should be re-classified as Li-normal. For the remaining stars, the high Li abundance must be a result of fresh synthesis of this fragile element. We identify two distinct episodes of Li production which occur in advanced evolutionary phases depending upon the mass of the star. We suggest that the Li-rich stars are formed mainly as a precursor to the deeper mixing process which produces anomalously low carbon isotopic ratios. Low-mass RGB stars, which later undergo the helium flash, produce Li at the phase referred to as the bump in the luminosity function. In intermediate-mass stars, the Li-rich phase occurs on the early-AGB. The compiled data provide constraints on the time scales for extra mixing and some insight on processes suggested in the literature. However, our results do not suggest any specific trigger mechanism. Since the Li-rich phases are extremely short, enrichment of the Li content of the ISM as a result of these episodes is negligible.

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Interpreting the Mg II h and k Line Profiles of Mira Variables

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We use radiative transfer calculations to reproduce the basic appearance of Mg II lines observed from Mira variables. These lines have centroids that are blueshifted by at least 30 km s^{-1} from the stellar rest frame. It is unlikely that flow velocities in the stellar atmospheres are this fast, so radiative transfer effects must be responsible for this behavior. Published hydrodynamic models predict the existence of cool, downflowing material above the shocked material responsible for the Mg II emission, and we demonstrate that scattering in this layer can result in Mg II profiles as highly blueshifted as those that are observed. However, our models also show that scattering *within* the shock plays an equally strong role in shaping the Mg II profiles, and our calculations illustrate the importance of partial redistribution and the effects of being out of ionization equilibrium.

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Structure and Evolution of Low-mass Population II Stars

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The focus of the present paper is on the detailed description of the internal structures of low mass, population II stars, to clarify some issues about these stellar models and, mainly, their present reliability for observational comparisons. We then explore 1) the role of the local convective model; 2) the differences between "grey" and "non grey" models, and between models in which the photospheric boundary conditions are set at different optical depths ($\tau_{\rm ph} = 3$ or 100); 3) the role of the equation of state (EoS), both in the atmospheric models and in the interior. One of the major conclusions of the paper is a cautionary note about the usage of the additive volume law in EoS calculations.

The dependence of the HR diagram locations and mass luminosity relations on metal and helium content are also discussed. A few comparisons with globular cluster stars show that: 1) general consistency of distance scales and morphologies in the HR diagram is found, when comparing ground based measurements in the Johnson B and V bands and observations in the HST bands; 2) a discrepancy between models and observations may exist for more metal rich clusters; 3) the plausible hypothesis that the mass function in the globular cluster NGC 6397 behaves smoothly until the lower limit of the main sequence poses constraints on the mass-luminosity relation at the lowest end of the main sequence.

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Multiwavelength Optical Observations of Chromospherically Active Binary Systems. III. High Resolution Echelle Spectra from Ca II H & K to Ca II IRT

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This is the third paper of a series aimed at studying the chromosphere of active binary systems using the information provided for several optical spectroscopic features. High resolution echelle spectra including all the optical chromospheric activity indicators from the Ca II H & K to Ca II IRT lines are analysed here for 16 systems. The chromospheric contribution in these lines has been determined using the spectral subtraction technique. Very broad wings have been found in the subtracted Hα profile of the very active star HU Vir. These profiles are well matched using a two-component Gaussian fit (narrow and broad) and the broad component can be interpreted as arising from microflaring. Red-shifted absorption features in the Hα line have been detected in several systems and excess emission in the blue wing of FG UMa was also detected. These features indicate that several dynamical processes, or a combination of them, may be involved. Using the $E_{H\alpha}/E_{H\beta}$ ratio as a diagnostic we have detected prominence-like extended material viewed off the limb in many stars of the sample, and prominences viewed against the disk at some orbital phases in the dwarfs OU Gem and BF Lyn. The He I D_3 line has been detected as an absorption feature in mainly all the giants of the sample. Total filling-in of the He I D_3, probably due to microflaring activity, is observed in HU Vir. Self-absorption with red asymmetry is detected in the Ca II H & K lines of the giants 12 Cam, FG UMa and BM CVn. All the stars analysed show clear filled-in Ca II IRT lines or even notable emission reversal. The small values of the E_{8542}/E_{8498} ratio we have found indicate Ca II IRT emission arises from plage-like regions. Orbital phase modulation of the chromospheric emission has been detected in some systems, in the case of HU Vir evidence of an active longitude area has been found.

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Non–LTE Treatment of Molecules in the Photospheres of Cool Stars

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We present a technique to treat systems with very many levels, like molecules, in non–LTE. This method is based on a superlevel formalism coupled with rate operator splitting. Superlevels consist of many individual levels that are assumed to be in LTE relative to each other. The usage of superlevels reduces the dimensionality of the rate equations dramatically and, thereby, makes the problem computationally more easily treatable. Our superlevel formalism retains maximum accuracy by using direct opacity sampling (dOS) when calculating the radiative transitions and the opacities. We developed this method in order to treat molecules in cool dwarf model calculations in non–LTE. Cool dwarfs have low electron densities and a radiation field that is far from a black body radiation field, both properties may invalidate the conditions for the common LTE approximation. Therefore, the most important opacity sources, the molecules, need to be treated in non–LTE. As a case study we applied our method to carbon monoxide. We find that our method gives accurate results since the conditions for the superlevel method are very well met for molecules. Due to very high collisional cross sections with hydrogen, and the high densities of H_2 the population of CO itself shows no significant deviation from LTE.

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Chemical Abundances in Seven Red Giants of NGC 2360 and NGC 2447

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Chemical abundances of about fifteen elements from oxygen to europium are measured in seven red giants of the two open clusters NGC 2360 and NGC 2447. The effective temperatures of the giants are determined spectroscopically by taking advantage of their known masses ($\sim 2\,M_\odot$ in NGC 2360 and $\sim 3\,M_\odot$ in NGC 2447) and bolometric magnitudes.

The average iron abundances we obtain for the two clusters are [Fe/H]=0.07 for NGC 2360 and [Fe/H]=0.03 for NGC 2447.

Evolutionary stellar model calculations are performed in the mass range $1-4\,M_\odot$ in order to analyze the surface Na and O abundances predicted after the first dredge-up. The sodium abundance shows a well defined correlation with stellar mass in the $2-3\,M_\odot$ range. The agreement between our Na abundance determinations in NGC 2360 and our model predictions at $2\,M_\odot$ is very good. In contrast, the overabundance in one of the three stars in NGC 2447 exceeds that predicted at $3\,M_\odot$ by $\sim$ 0.08 dex, which is significant compared to the observational error bars. The effects of core overshooting, convection prescription, metallicity and nuclear reaction rates on the Na surface predictions of our models are investigated.

An oxygen deficiency relative to iron by 0.2 dex is measured in our stars, in disagreement with our model predictions. Assuming that the Sun is 0.1–0.3 dex enriched in oxygen relative to neighbor stars could explain the discrepancy.

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High Resolution X-Ray Spectra of Capella: Initial Results from the Chandra High Energy Transmission Grating Spectrometer

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High resolution spectra of the active binary Capella (G8 III + G1 III) covering the energy range 0.4-8.0 keV (1.5-30Å) show a large number of emission lines, demonstrating the performance of the HETGS. A preliminary application of plasma diagnostics provides information on coronal temperatures and densities. Lines arising from different elements in a range of ionization states indicate that Capella has plasma with a broad range of temperatures, from $\log T =$ 6.3 to 7.2, generally consistent with recent results from observations with the Extreme Ultraviolet Explorer (EUVE) and the Advanced Satellite for Cosmology and Astrophysics (ASCA). The electron density is determined from He-like O VII lines, giving the value $N_e \sim 10^{10}\mathrm{cm}^{-3}$ at $T_e \sim 2 \times 10^6$K; He-like lines formed at higher temperatures give only upper limits to the electron density. The density and emission measure from O VII lines together indicate that the coronal loops are significantly smaller than the stellar radius.

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Chromospheric Two-Component NLTE Modelling of the Binary System V 711 Tau = HR 1099

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In this paper we present the first two-component, semi-empirical chromospheric model of the RS CVn binary system V 711 Tau based on detailed fits of Hα and Mg II h line profiles.

Synthetic Hα and Mg II h line profiles are computed by means of NLTE radiative transfer calculations. Using the observed Emission Measure distribution to constrain the transition region structure and the photospheric *Next-Generation* model with log(g)=3.5 and $T_{\rm eff}$ =4800 K, we have built a grid of chromospheric models for the K1 IV component of the binary system by means of spline interpolations between photospheric and transition region models. With such interpolations the free parameters are restricted to the temperature minimum and the position of an interpolation knot. We find that a mean single-component model cannot satisfactorily reproduce the observed line profiles. Chromospheric Doppler Imaging is then used to consider the chromospheric emission as due to two different components of known surface coverage and emission. Extensive grids of semi-empirical chromospheric models are built separately for the two components and the weighted-combined synthetic Hα and Mg II h profiles are compared with observations. Two-component synthetic line profiles reproduce the observed Hα and Mg II h in detail, indicating that the *broad* and *narrow* components can be interpreted in terms of radiative transfer effects in different atmospheric structures for the active and quiet regions. From this analysis we infer information on physical properties of the active region, from which the *broad* component originates, with respect to the remaining chromosphere from which the *narrow* component originates. We show also that the variability outside flares can be reproduced considering slightly different models for the active region.

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The Henize Sample of S Stars: II. Data

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This paper presents data collected on the Henize sample of 205 S stars: (i) CORAVEL radial-velocity data; (ii) photometric data in the UBV bands of the Geneva photometric system; (iii) photometric data in the $JHKL$ bands of the SAAO photometric system; (iv) IRAS fluxes; (v) low-resolution spectra of 158 S stars. Close visual companions have been found for Hen 47, 94, 105 and 155. Spectroscopic orbital elements are provided for Hen 2, 108, 121, 137 and 147. The analysis of these data is presented in a companion paper.

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The Henize Sample of S stars: III. Uncovering the Binary Intruders

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The properties of S stars are investigated thanks to a large observing program devoted to the well-defined Henize sample (205 S stars south of $\delta = -25°$ and brighter than $R = 10.5$, covering all galactic latitudes), in order to derive the respective properties of the intrinsic S stars (genuine thermally-pulsing AGB stars) and of the extrinsic S stars (post mass-transfer binaries).

The stellar sample is first cleaned from a few stars misclassified as S thanks to UBV Geneva photometry and low-resolution spectroscopy. These low-resolution spectra also allow to successfully distinguish subclasses within the S star family. Dedicated Geneva photometry and high-resolution spectroscopy have led to the discovery of two symbiotic S stars.

The more stringent difference between extrinsic and intrinsic stars is their technetium content, but several other observational parameters are shown to be efficient to some extent in segregating intrinsic S stars from their extrinsic masqueraders (UBV, $JHKL$ and IRAS photometry, radial-velocity standard deviation, shape of the CORAVEL cross-correlation dip, combination of band strength indices derived from low-resolution spectra). Multivariate classification has been performed on the Henize data sample in order to guarantee a classification as objective as possible and handling at the same time a large number of parameters. The resulting clusters separate efficiently extrinsic and intrinsic S stars, allowing to derive the respective properties of these two distinct stellar classes. The population difference between intrinsic and extrinsic S stars is for the first time clearly demonstrated, since intrinsic S stars are far more concentrated towards the galactic plane than extrinsic S stars ($z_{\rm int} = 200 \pm 100$ pc and $z_{\rm ext} = 600 \pm 100$ pc), and are therefore believed to belong to a younger, more massive population. The frequency of extrinsic and intrinsic S stars in the magnitude-limited Henize sample amounts to 33% and 67%, respectively. In a volume-limited sample, this proportion is subject to large uncertainties mainly because of uncertain luminosities. There are probably as many as 40% extrinsic stars among S stars in a volume-limited sample.

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Solar Abstracts

Multi-Component Structure of Solar and Stellar Transition Regions

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Emission lines from the solar transition region between the chromosphere and the corona often show a two Gaussian component profile with a core and a broad second component contributing up to 25% to the total intensity. For the first time a systematic study of the broadening *and* Doppler shift of the second weaker components is performed using SUMER on SOHO to explore the spatial structures of the second components.

It is found that the two component structure is basically restricted to the bright chromospheric network. The narrow core component shows the familiar transition region redshifts, with hardly any blueshifts in the network. The broad second components are blueshifted compared to the core, but are still predominantly redshifted. However, quite large areas in the network (up to $20'' \times 20''$) show concentrations of blueshifts in the second component. In the inter-network the line profile has a single Gaussian shape and shows small red- and also some blueshifts.
It is suggested that the two components in the network correspond with two spatially unresolved physical regimes in quiet Sun network: small scale loops and larger scale coronal loop structures anchored in the network. The footpoint regions of the latter are of a funnel-type and form a "canopy" above inter-network regions of the chromosphere. Shocks propagating upward from the non-magnetic chromosphere interact with this canopy, which leads to the transition region inter-network emission. A further analysis, especially of emission lines originating from higher temperatures, is required to confirm this scenario.
The distribution and correlations of the line intensities, shifts and widths show that these physical regimes are heated by different mechanisms. This sheds new light on the interpretation of stellar observations in terms of coronal heating. A comparison to existing studies of stellar transition regions shows the need for more thorough theoretical investigations on the formation of stellar transition region lines.

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Solar Flare Radio Pulsations as a Signature of Dynamic Magnetic Reconnection

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Decimetric radio observations of the impulsive solar flare on October 5, 1992, 09:25 UT show a long series of quasi-periodic pulsations deeply modulating a continuum in the 0.6–2 GHz range that is slowly drifting toward lower frequencies. We propose a model in which the pulsations of the radio flux are caused by quasi-periodic particle acceleration episodes that result from a dynamic phase of magnetic reconnection in a large-scale current sheet. The reconnection is dominated by repeated formation and subsequent coalescence of magnetic islands (known as "secondary tearing" or "impulsive bursty" regime of reconnection), while a continuously growing plasmoid is fed by newly coalescing islands. Such a model, involving a current sheet and a growing plasmoid, is consistent with the Yohkoh observations of the same flare (Ohyama & Shibata 1998, ApJ 499, 934). We present two-dimensional MHD simulations of dynamic magnetic reconnection that support the model. Within the framework of the proposed interpretation, the radio observations reveal details of plasmoid formation in flares.

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Flare Energy Release by Flux Pile-up Magnetic Reconnection in a Turbulent Current Sheet

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The power output of flux pile-up magnetic reconnection is known to be determined by the total hydromagnetic pressure outside the current sheet. The maximum energy release rate is reached for optimised solutions that balance the maximum dynamic and magnetic pressures. An optimised solution is determined in this paper for a current sheet with turbulent electric resistivity. The resulting energy dissipation rate W_a is a strong function of the maximum, saturated magnetic field B_s: $W_\mathrm{a} \sim B_\mathrm{s}^4$. Numerically, W_a can exceed the power output based on the classical resistivity by more than two orders of magnitude for three-dimensional pile-up, leading to solar flare-like energy release rates of order 10^{28} erg s^{-1}. It is also shown that the optimisation prescription has its physical basis in relating the flux pile-up

solutions to the Sweet–Parker reconnection model.

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On the Magnetic Field Orientation and Plasma Flows in Solar Filament Barbs

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Speeds of vertical flows in quiescent solar filaments are typically much less than the local Alfvén speed. This is why the flows in filament barbs can be modeled by perturbing a magnetostatic solution describing a balance between the Lorentz force, gravity, and gas pressure in a barb. This approach explains why some of the flows are neither aligned with the magnetic field nor controlled by gravity. Both the observed upflows and the magnetic field dips in barbs are likely to be caused by photospheric magnetic reconnection.

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Structure and Dynamics of an Active Region Loop System Observed on the Solar Disc with SUMER on SOHO

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In this paper we present and discuss spectra obtained by SUMER on SOHO from an active region loop system observed on the solar disc, close to the central meridian, on July 26th, 1996. The region was observed with a spatial resolution of about $2''$ by $2''$ in emission lines forming in the transition region and inner corona, with the aim of investigating the physical structure and dynamical behaviour of the plasma in active region magnetic loops. To this purpose we have reduced and analysed the spectral observations in order to determine the values of intensity, Doppler shift and line profile width for the selected emission lines in all the spatially resolved elements of the examined area of the solar disc. By comparing intensity, velocity maps and photospheric magnetic fields obtained by MDI on SOHO, several magnetic loops have been identified, some of which contemporarily appear over a range of temperatures, while others are compact and only visible in a limited temperature range. A few loops exhibit velocity fields typical of siphon flows, the siphon-like velocities being higher in compact loops. Two compact loops seen in the transition region lines show asymmetric siphon-like velocity fields and high non-thermal velocities at the *upflowing* footpoint. High non-thermal velocities are also associated with the falling footpoint of a larger loop. Besides such loops, other bright features are observed in the transition region lines, whose morphology cannot be identified as arch-like. They have no coronal counterpart, are red-shifted with respect to the median line centroid position and exhibit high non-thermal velocities.

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Spectroscopic Transit by the Planet Orbiting the Star HD209458

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We report the first detection of a planetary transit by spectroscopic measurements. We have detected the distortion of the stellar line profiles during a planetary transit. With the ELODIE spectrograph we took a sequence of high precision radial velocities of the star HD209458 at time of a transit of its planet. We detected an anomaly in the residuals of the orbit. The shape and the amplitude of the anomaly are modeled as a change of the mean stellar line profile resulting from the planet crossing the disk of the rotating star. The planetary orbit is in the same direction as the stellar rotation. Using the photometric transit to constrain the timing and the impact parameters of the transit, we measure an angle $\alpha = 3.9$ [^{0}] between the orbital plane and the *apparent equatorial plane* as well as a $v \sin i = 3.75 \pm 1.25\,\mathrm{km\,s^{-1}}$. With additional constrains on the inclination of the star and on the statistics of the line of sight distribution, we can set an upper limit of $30^{\,0}$ to the angle between the orbital plane and the stellar equatorial plane.

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Membership and Multiplicity among Very Low-Mass Stars and Brown Dwarfs in the Pleiades Cluster

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We present near-infrared photometry and optical spectroscopy of very low-mass stars and brown dwarf candidates in the Pleiades open cluster. The membership status of these objects is assessed using color-magnitude diagrams, lithium and spectral types. Eight objects out of 45 appear to be non-members. A search for companions among 34 very low-mass Pleiades members ($M \leq 0.09\ M_\odot$) in high-spatial resolution images obtained with the Hubble Space Telescope and the adaptive optics system of the Canada-France-Hawaii telescope produced no resolved binaries with separations larger than 0.2 arcsec (a$\sim$27 AU; P$\sim$444 years). Nevertheless, we find evidence for a binary sequence in the color-magnitude diagrams, in agreement with the results of Steele & Jameson (1995) for higher mass stars. We apply the lithium test to two objects: CFHT-Pl-16, which lies in the cluster binary sequence but is unresolved in images obtained with the Hubble Space Telescope; and CFHT-Pl-18, which is binary with 0".33 separation (Martín et al. 1998). The first object passes the test, but the second object does not. We conclude that CFHT-Pl-16 is a likely Pleiades brown dwarf binary with separation <11 AU, and that CFHT-Pl-18 is a foreground system. We compare the multiplicity statistics of the Pleiades very low-mass stars and brown dwarfs with that of G and K-type main sequence stars in the solar neighborhood (Duquennoy & Mayor 1991). We find that there is some evidence for a deficiency of wide binary systems (separation >27 AU) among the Pleiades very low-mass members. We briefly discuss how this result can fit with current scenarios of brown dwarf formation. We correct the Pleiades substellar mass function for the contamination of cluster non-members found in this work. We find a contamination level of 33% among the brown dwarf candidates identified by Bouvier et al. (1998). Assuming a power law IMF across the substellar boundary, we find a slope $dN/dM \sim M^{-0.53}$, implying that the number of objects per mass bin is still rising but the contribution to

the total mass of the cluster is declining in the brown dwarf regime.

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Theory of Low-Mass Stars and Substellar Objects

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Since the discovery of the first bona-fide brown dwarfs and extra-solar planets in 1995, the field of low mass stars and substellar objects has considerably progressed, both from theoretical and observational viewpoints. Recent developments in the physics entering the modeling of these objects have led to significant improvements in the theory and to a better understanding of their mechanical and thermal properties. This theory can now be confronted with observations directly in various observational diagrams (color-color, color-magnitude, mass-magnitude, mass-spectral type), a stringent and unavoidable constraint which became possible only recently, with the generation of synthetic spectra. In this paper, we present the current state-of-the-art general theory of low-mass stars and sub-stellar objects, from one solar mass to one Jupiter mass, regarding primarily their interior structure and evolution. This review is a natural complement to the previous review on the atmosphere of low-mass stars and brown dwarfs (Allard et al 1997). Special attention is devoted to the comparison of the theory with various available observations. The contribution of low-mass stellar and sub-stellar objects to the Galactic mass budget is also analysed.

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