COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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Stellar Abstracts

Planetary Systems around Close Binary Stars: The Case of the Very Dusty, Sun-like Spectroscopic Binary BD +20 307

B. Zuckerman[1,2], Francis C. Fekel[3], Michael H. Williamson[3], Gregory W. Henry[3], and M. P. Muno[4]

[1] Dept. of Physics & Astronomy, Univ. of California, Los Angeles, CA 90095
[2] UCLA Center for Astrobiology
[3] Center of Excellence in Info. Systems, Tennessee State Univ., 3500 John A. Merritt Blvd., Box 9501, Nashville, TN 37209
[4] Space Radiation Laboratory, California Institute of Technology, Pasadena, CA 91125

Field star BD +20 307 is the dustiest known main-sequence star, based on the fraction of its bolometric luminosity, ∼4%, that is emitted at infrared wavelengths. The particles that carry this large IR luminosity are unusually warm, comparable to the temperature of the zodiacal dust in the solar system, and their existence is likely to be a consequence of a fairly recent collision of large objects such as planets or planetary embryos. Thus, the age of BD +20 307 is potentially of interest in constraining the era of terrestrial planet formation. The present project was initiated with an attempt to derive this age using the *Chandra X-ray Observatory* to measure the X-ray flux of BD +20 307 in conjunction with extensive photometric and spectroscopic monitoring observations from Fairborn Observatory. However, the recent realization that BD +20 307 is a short period, double-line, spectroscopic binary whose components have very different lithium abundances, vitiates standard methods of age determination. We find the system to be metal-poor; this, combined with its measured lithium abundances, indicates that BD +20 307 may be several to many Gyr old. BD +20 307 affords astronomy a rare peek into a mature planetary system in orbit around a close binary star (because such systems are not amenable to study by the precision radial velocity technique).

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For preprints contact: ben@astro.ucla.edu

Carbon Abundances of Three Carbon-Enhanced Metal-Poor Stars from High-Resolution Gemini-S/bHROS Spectra of the λ8727 [C I] Line

S.C. Schuler[1], S.J. Margheim[2], T. Sivarani[3], M. Asplund[4], V.V. Smith[1], K. Cunha[1] and T.C. Beers[3]

[1] National Optical Astronomy Observatory/Cerro Tololo Inter-American Observatory, Casilla 603, La Serena, Chile
[2] Gemini Observatory, Casilla 603, La Serena, Chile
[3] Department of Physics and Astronomy, Center for the Study of Cosmic Evolution, and Joint Institute for Nuclear Astrophysics, Michigan State University, East Lansing, MI
[4] Max Planck Institute for Astrophysics, Postfach 1317, 85741, Garching, Germany

We present the results from an analysis of the λ8727 forbidden [C I] line in high-resolution Gemini-S/bHROS spectra of three Carbon-Enhanced Metal-Poor (CEMP) stars. We find the [C/Fe] ratios based on the [C I] abundances of the two most Fe-rich stars in our sample (HE 0507-1653: [Fe/H] = −1.42 and HE 0054-2542: [Fe/H] = −2.66) to be in good agreement with previously determined CH and C_2 line-based values. For the most Fe-deficient star in our sample (HE 1005-1439: [Fe/H] = −3.08), however, the [C/Fe] ratio is found to be 0.34 dex lower than the published molecular-based value. We have carried out 3D local thermodynamic equilibrium (LTE) calculations for [C I], and the resulting corrections are found to be modest for all three stars, suggesting that the discrepancy between the [C I] and molecular-based C abundances of HE 1005-1439 is due to more severe 3D effects on the molecular lines. Carbon abundances are also derived from C I high-excitation lines and are found to be 0.45 − 0.64 dex higher than the [C I]-based abundances. Previously published non-LTE (NLTE) C I abundance corrections bring the [C I] and C I abundances into better agreement; however, targeted NLTE calculations for CEMP stars are clearly needed. We have also derived the abundances of nitrogen, potassium, and iron for each star. The Fe abundances agree well with previously derived values, and the K abundances are similar to those of C-normal metal-poor stars. Nitrogen abundances have been derived from resolved lines of the CN red system assuming the C abundances derived from the [C I] feature. The abundances are found to be approximately 0.44 dex larger than literature values, which have been derived from CN blue bands near 3880 and 4215 Å. We discuss evidence that suggests that analyses of the CN blue system bands underestimate the N abundances of metal-poor giants.

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For preprints contact: sschuler@ctio.noao.edu

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Observation and Modelling of Main Sequence Stellar Chromospheres; VII Rotation and Metallicity of dM1 Stars

E.R. Houdebine[1]

[1] 25 Rue du Dr. Laulaigne, 49670 Valanjou, France

We have measured vsini and metallicity from high resolution spectroscopic observations of a selected sample of dM1 type stars. To measure vsini we first selected three template stars known for their slow rotation or their very low activity levels and then cross-correlated their spectra with those of our target stars. The excess broadening of the cross-correlation peaks gives vsini. For metallicity, we compiled all available measurements from the literature and correlated them with the stellar radius. Providing the parallax is known, This new method allows us to derive metallicities for all our target stars.

We measured vsini to an accuracy of 2 km/s. These values were combined with other measurements taken from the literature. We have detected rotation in 7 dM1e stars and 11 dM1 stars and upper limits for 20 other dM1 stars. Our results show that the distribution of the rotation period msy be bimodal for dM1 stars, i.e., there are two groups of stars: the fast rotators with P_{rot} ∼6 days and the slow rotators with P_{rot} ∼24 days. There is a gap between these two groups.

We obtained a correlation between metallicity and stellar radius which allows us to derive metallicities for all stars in our sample and more generally for all dM1 stars with [M/H] in the range -1.5 to 0.5 Dex, with a reasonable accuracy. We compare this correlation to models and find a significant disagreement in radii. However, the observed shape of the correlation is globally reproduced by the models. We derive the metallicity for 87 M1 dwarfs and subdwarfs.

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For preprints contact: eric_houdebine@yahoo.fr

Coronal Properties of the EQ Peg Binary System

C. Liefke[1], J.-U. Ness[2], J. H. M. M. Schmitt[1] and A. Maggio[3]

[1] Hamburger Sternwarte, Gojenbergsweg 112, 21029 Hamburg, Germany
[2] Arizona State University, School of Earth and Space Exploration, ASU, P. O. Box 871404,Tempe, AZ 85287, USA
[3] INAF – Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy

The activity indicators of M dwarfs are distinctly different for early and late types. The coronae of early M dwarfs display high X-ray luminosities and temperatures, a pronounced inverse FIP effect, and frequent flaring to the extent that no quiescent level can be defined in many cases. For late M dwarfs, fewer but more violent flares have been observed, and the quiescent X-ray luminosity is much lower. To probe the relationship between coronal properties with spectral type of active M dwarfs, we analyze the M3.5 and M4.5 components of the EQ Peg binary system in comparison with other active M dwarfs of spectral types M0.5 to M5.5. We investigate the timing behavior of both components of the EQ Peg system, reconstruct their differential emission measure, and investigate the coronal abundance ratios based on emission-measure independent line ratios from their *Chandra* HETGS spectra. Finally we test for density variations in different states of activity. The X-ray luminosity of EQ Peg A (M3.5) is by a factor of 6–10 brighter than that of EQ Peg B (M4.5). Like most other active M dwarfs, the EQ Peg system shows an inverse FIP effect. The abundances of both components are consistent within the errors; however, there seems to be a tendency toward the inverse FIP effect being less pronounced in the less active EQ Peg B when comparing the quiescent state of the two stars. This trend is supported by our comparison with other M dwarfs.As the X-ray luminosity decreases with later spectral type, so do coronal temperatures and flare rate. The amplitude of the observed abundance anomalies, i. e. the inverse FIP effect, declines; however, clear deviations from solar abundances remain.

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For preprints contact: cliefke@hs.uni-hamburg.de

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Solar Abstracts

History of Solar Activity Over Millennia

Ilya G. Usoskin[1]

[1] Sodankylä Geophysical Observatory (Oulu unit), University of Oulu, Finland

A review of the present knowledge of the long-term behaviour of solar activity on multimillenial time scale, as reconstructed using the indirect proxy method, is presented here. The very concept of solar activity is discussed along with an overview of special indices used to quantify different aspects of the variable solar activity, with special emphasis upon the sunspot number. On longer time scales, quantitative information on the past solar activity can only be obtained using the method based upon indirect proxy, such as cosmogenic isotopes ^{14}C and ^{10}Be in natural stratified archives (tree rings or ice cores). A historical overview and the modern state of development of the proxy-based method of the past solar activity reconstruction over millennia are discussed. Special attention is paid upon verifications and inter-calibration of the reconstructions. It is argued that the method of cosmogenic isotopes makes a solid basis for studies of solar variability in the past on the long-term scale (centennia to millennia) during the Holocene. A separate section is devoted to reconstructions of strong solar energetic particle (SEP) events in the past, that suggests that the present-day average SEP flux is broadly consistent with the estimates on longer time scales, and occurrence of extra-strong events is unlikely. Finally, the main features of the long-term evolution of solar magnetic activity, including the statistics of Grand minima and maxima occurrence, are summarized and their possible implications especially for solar/stellar dynamo theory are discussed.

To be published by *Living Reviews in Solar Physics*

For preprints contact: ilya.usoskin@oulu.fi (continued→)

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Radiative MHD Simulation of Sunspot Structure

M. Rempel[1], M. Schüssler[2] and M. Knölker[1]

[1] High Altitude Observatory, NCAR, P.O. Box 3000, Boulder, Colorado 80307, USA
[2] Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany

Results of a 3D MHD simulation of a sunspot with a photospheric size of about 20 Mm are presented. The simulation has been carried out with the MURaM code, which includes a realistic equation of state with partial ionization and radiative transfer along many ray directions. The largely relaxed state of the sunspot shows a division in a central dark umbral region with bright dots and a penumbra showing bright filaments of about 2 to 3 Mm length with central dark lanes. By a process similar to the formation of umbral dots, the penumbral filaments result from magneto-convection in the form of upflow plumes, which become elongated by the presence of an inclined magnetic field: the upflow is deflected in the outward direction while the magnetic field is weakened and becomes almost horizontal in the upper part of the plume near the level of optical depth unity. A dark lane forms owing to the piling up of matter near the cusp-shaped top of the rising plume that leads to an upward bulging of the surfaces of constant optical depth. The simulated penumbral structure corresponds well to the observationally inferred interlocking-comb structure of the magnetic field with Evershed outflows along dark-laned filaments with nearly horizontal magnetic field and overturning perpendicular ('twisting') motion, which are embedded in a background of stronger and less inclined field. Photospheric spectral lines are formed at the very top and somewhat above the upflow plumes, so that they do not fully sense the strong flow as well as the large field inclination and significant field strength reduction in the upper part of the plume structures.

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For preprints contact: rempel@hao.ucar.edu

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Coupling from the Photosphere to the Chromosphere and the Corona

Sven Wedemeyer-Böhm[1], Andreas Lagg[2] and Åke Nordlund [3]

[1] Institute of Theoretical Astrophysics, University of Oslo, Norway,
[2] Max Planck Institute for Solar System Research, Katlenburg- Lindau, Germany
[3] Niels Bohr Institute, University of Copenhagen, Denmark

The atmosphere of the Sun is characterized by a complex interplay of competing physical processes: convection, radiation, conduction, and magnetic fields. The most obvious imprint of the solar convection and its overshooting in the low atmosphere is the granulation pattern. Beside this dominating scale there is a more or less smooth distribution of spatial scales, both towards smaller and larger scales, making the Sun essentially a multi-scale object. Convection and overshooting give the photosphere its face but also act as drivers for the layers above, namely the chromosphere and corona. The magnetic field configuration effectively couples the atmospheric layers on a multitude of spatial scales, for instance in the form of loops that are anchored in the convection zone and continue through the atmosphere up into the chromosphere and corona. The magnetic field is also an important structuring agent for the small, granulation-size scales, although (hydrodynamic) shock waves also play an important role — especially in the internetwork atmosphere where mostly weak fields prevail. Based on recent results from observations and numerical simulations, we attempt to present a comprehensive picture of the atmosphere of the quiet Sun as a highly intermittent and dynamic system.

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For preprints contact: svenwe@astro.uio.no

Binary Frequency of Very Young Brown Dwarfs at Separations Smaller Than 3 AU

Viki Joergens[1]

[1] Max-Planck Institute for Astronomy Heidelberg, Germany

Searches for companions of brown dwarfs by direct imaging probe mainly orbital separations greater than 3–10 AU. On the other hand, previous radial velocity surveys of brown dwarfs are mainly sensitive to separations smaller than 0.6 AU. It has been speculated if the peak of the separation distribution of brown dwarf binaries lies right in the unprobed range. The present work for the first time extends high-precision radial velocity surveys of brown dwarfs out to 3 AU. Based on more than six years UVES/VLT spectroscopy the binary frequency of brown dwarfs and (very) low-mass stars (M4.25-M8) in Chamaeleon I was determined: it is 18^{+20}_{-12} % for the whole sample and 10^{+18}_{-8} % for the subsample of ten brown dwarfs and very low-mass stars (M≤ 0.1 $M_\odot$). Two spectroscopic binaries were confirmed, these are the brown dwarf candidate ChaHα 8 (previously discovered by Joergens & Müller), and the low-mass star CHXR 74. Since their orbital separations appear to be 1 AU or greater, the binary frequency at <1 AU might be less than 10%. Now for the first time companion searches of (young) brown dwarfs cover the whole orbital separation range and the following observational constraints for models of brown dwarf formation can be derived: (i) the frequency of brown dwarf and very low-mass stellar binaries at <3 AU is not significantly exceeding that at >3 AU; i.e. direct imaging surveys do not miss a significant fraction of brown dwarf binaries; (ii) the overall binary frequency of brown dwarfs and very low- mass stars is 10-30 %; (iii) the decline of the separation distribution of brown dwarfs towards smaller separations seem to occur between 1 and 3 AU; (iv) the observed continuous decrease of the binary frequency from the stellar to the substellar regime is confirmed at <3 AU providing further evidence for a continuous formation mechanism from low-mass stars to brown dwarfs.

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For preprints contact: viki@mpia.de

For preprints via ftp or WWW: http://www.mpia.de/homes/joergens/refpublications.html

The Palomar/Keck Adaptive Optics Survey of Young Solar Analogs: Evidence for a Universal Companion Mass Function

Stanimir Metchev[1,2] **and Lynne A. Hillenbrand**[3]

[1] Dept. of Physics & Astronomy, 430 Portola Plaza, Univ. of California, Los Angeles, CA 90095–1547 USA
[2] Dept. of Physics & Astronomy, State Univ. of New York, Stony Brook, NY 11794–3800 USA (current address)
[3] Dept. of Astronomy, California Inst. of Technology, Pasadena, CA 91125 USA

We present results from an adaptive optics survey for substellar and stellar companions to Sun-like stars. The survey targeted 266 F5–K5 stars in the 3 Myr to 3 Gyr age range with distances of 10–190 pc. Results from the survey include the discovery of two brown dwarf companions (HD 49197B and HD 203030B), 24 new stellar binaries, and a triple system. We infer that the frequency of 0.012–0.072 $M_\odot$ brown dwarfs in 28–1590 AU orbits around young solar analogs is $3.2^{+3.1}_{-2.7}$% (2σ limits). The result demonstrates that the deficiency of substellar companions at wide orbital separations from Sun-like stars is less pronounced than in the radial velocity "brown dwarf desert." We infer that the mass distribution of companions in 28–1590 AU orbits around solar-mass stars follows a continuous $dN/dM_2 \propto M_2^{-0.4}$ relation over the 0.01–1.0 $M_\odot$ secondary mass range. While this functional form is similar to the that for <0.1 $M_\odot$ isolated objects, over the entire 0.01–1.0 $M_\odot$ range the mass functions of companions and of isolated objects differ significantly. Based on this conclusion and on similar results from other direct imaging and radial velocity companion surveys in the literature, we argue that the companion mass function follows the same universal form over the entire range between 0–1590 AU in orbital semi-major axis and ≈0.01–20 $M_\odot$ in companion mass. In this context, the relative dearth of substellar versus stellar secondaries at *all* orbital separations arises naturally from the inferred form of the companion mass function.

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For preprints contact: metchev@astro.sunysb.edu

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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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