COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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Stellar Abstracts

Magnetic Flux Transport on Active Cool Stars and Starspot Lifetimes

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Many rapidly rotating cool stars show signatures of large magnetic regions at all latitudes. Mid-latitude starspots and magnetic regions have characteristic lifetimes of 1 month or less, as indicated by observations using (Zeeman-) Doppler imaging techniques. We aim to estimate the lifetimes of bipolar magnetic regions and starspots on the surfaces of cool stars. We consider different possible configurations for starspots and compare their flux variations and lifetimes based on a magnetic flux transport model. We carry out numerical simulations of the surface evolution of bipolar magnetic regions (BMRs) and magnetic spots on stars, which have radii and surface rotational shears of AB Doradus, the Sun, and the HR 1099 primary. The surface flux transport model is based on the magnetic induction equation for radial fields under the effects of surface differential rotation, meridional flow, and turbulent diffusion due to convective flow patterns. We calculate the flux evolution and the lifetimes of BMRs and unipolar starspots, varying the emergence latitude, surface shear rate, and tilt angle. For BMRs comparable to the largest observed on the Sun, we find that varying the surface flows and the tilt angle modifies the lifetimes over a range of one month. For very large BMRs (area $\sim$10% of the stellar surface) the assumption of a tilt angle increasing with latitude leads to a significant increase of lifetime, as compared to the case without tilt. Such regions can evolve to polar spots that live more than a year. Adopting the observed weak latitudinal shear and the radius of the active subgiant component of HR 1099, we find longer BMR lifetimes as compared to the more strongly sheared AB Dor case. Random emergence of six additional tilted bipoles in an activity belt at 60° latitude enhanced the lifetimes of polar caps up to 7 years. We have also compared the evolution and lifetime of monolithic starspots with those of conglomerates of smaller spots of similar total area. We find similar decay patterns and lifetimes for both configurations.

Accepted by A&A

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For preprints via WWW: http://arxiv.org/abs/astro-ph/0612399

Rubidium-Rich Asymptotic Giant Branch Stars

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A long-debated issue concerning the nucleosynthesis of neutron-rich elements in asymptotic giant branch (AGB) stars is the identification of the neutron source. We report intermediate-mass (4 to 8 solar masses) AGB stars in our Galaxy that are rubidium-rich as a result of overproduction of the long-lived radioactive isotope ^{87}Rb, as predicted theoretically 40 years ago. This finding represents direct observational evidence that the ^{22}Ne(α,n)^{25}Mg reaction must be the dominant neutron source in these stars. These stars challenge our understanding of the late stages of the evolution of intermediate-mass stars and would have promoted a highly variable Rb/Sr environment in the early solar nebula.

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Structured Red Giant Winds with Magnetized Hot Bubbles and the Corona/Cool Wind Dividing Line

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By performing magnetohydrodynamical (MHD) simulations, we investigate the mass loss of intermediate- and low-mass stars from main sequence (MS) to red giant branch (RGB) phases. Alfvén waves, which are excited by the surface convections travel outwardly and dissipate by nonlinear processes to accelerate and heat the stellar winds. We dynamically treat these processes in open magnetic field regions from the photospheres to $\simeq$25 stellar radii. When the stars evolve to slightly blueward positions of the dividing line (Linsky & Haisch), the steady hot corona with temperature, $T \approx 10^6$ K, suddenly disappears. Instead, many hot ($\sim 10^6$ K) and warm ($\geq 10^5$ K) bubbles are formed in cool ($T \leq 2 \times 10^4$ K) chromospheric winds because of thermal instability; the red giant wind is not a steady stream but structured outflow. As a result, the mass loss rates, $\dot{M}$, largely vary in time by 3-4 orders or magnitude in the RGB stars. Supported by magnetic pressure, the density of hot bubbles can be kept low to reduce the radiative cooling and to maintain the high temperature long time. Even in the stars redward of the dividing line, hot bubbles intermittently exist, and they can be sources of ultraviolet/soft X-ray emissions from hybrid stars. Nearly static regions are formed above the photospheres of the RGB stars, and the stellar winds are effectively accelerated from several stellar radii. Then, the wind velocity is much smaller than the surface escape speed, because it is regulated by the slower escape speed at that location. We finally derive an equation that determines $\dot{M}$ from the energetics of the simulated wave-driven winds in a *forward* manner. The relation explains $\dot{M}$ from MS to RGB, and it can play a complementary role to the Reimers' formula, which is mainly for more luminous gaints.

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For preprints via ftp or WWW: astro-ph/0608195

Solar Abstracts

Carbon Monoxide in the Solar Atmosphere II. Radiative Cooling by CO Lines

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Aims: The role of carbon monoxide as a cooling agent for the thermal structure of the mid-photospheric to low-chromospheric layers of the solar atmosphere in internetwork regions is investigated.
Methods: The treatment of radiative cooling via spectral lines of carbon monoxide (CO) has been added to the radiation chemo-hydrodynamics code CO5BOLD. The radiation transport has now been solved in a continuum band with Rosseland mean opacity and an additional band with CO opacity. The latter is calculated as a Planck mean over the CO band between 4.4 and 6.2 μm. The time-dependent CO number density is derived from the solution of a chemical reaction network.
Results: The CO opacity indeed causes additional cooling at the fronts of propagating shock waves in the chromosphere. There, the time-dependent approach results in a higher CO number density compared to the equilibrium case and hence in a larger net radiative cooling rate. The average gas temperature stratification of the model atmosphere, however, is only reduced by roughly 100 K. Also the temperature fluctuations and the CO number density are only affected to small extent. A numerical experiment without dynamics shows that the CO cooling process works in principle and drives the atmosphere to a cool radiative equilibrium state. At chromospheric heights, the radiative relaxation of the atmosphere to a cool state takes several 1000 s. The CO cooling process thus would seem to be too slow compared to atmospheric dynamics to be responsible for the very cool temperature regions observed in the solar atmosphere.
Conclusions: The hydrodynamical timescales in our solar atmosphere model are much too short to allow for the radiative relaxation to a cool state, thus suppressing the potential thermal instability due to carbon monoxide as a cooling agent. Apparently, the thermal structure and dynamics of the outer model atmosphere are instead determined primarily by shock waves.

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The Post-Eruptive Evolution of a Coronal Dimming

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We discuss the post-eruptive evolution of a “coronal dimming” based on observations of the EUV corona from the Solar and Heliospheric Observatory and the Transition Region and Coronal Explorer. This discussion highlights the roles played by magnetoconvection-driven magnetic reconnection and the global magnetic environment of the plasma in the “filling” and apparent motion of the region following the eruption of a coronal mass ejection (CME). A crucial element in our understanding of the dimming region evolution is developed by monitoring the disappearance and reappearance of bright TRACE “moss” around the active region giving rise to the CME. We interpret the change in the TRACE moss as a proxy of the changing coronal magnetic field topology behind the CME front. We infer that the change in global magnetic topology also results in a shift of energy balance in the process responsible for the production of the moss emission while the coronal magnetic topology evolves from closed, to open and back to closed again because, following the eruption, the moss reforms around the active region in almost exactly its pre-event configuration. As a result of the moss evolution, combining our discussion with recent spectroscopic results of an equatorial coronal hole, we suggest that the interchangeable use of the term “transient coronal hole” to describe a coronal dimming is more

than just a simple coincidence.

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For preprints via ftp or WWW: http://lanl.arxiv.org/abs/astro-ph/0701347

Empirical Solar Wind Forecasting from the Chromosphere

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Recently, we correlated the inferred structure of the solar chromospheric plasma topography with solar wind velocity and composition data measured at 1 AU. We now offer a physical justification of these relationships and present initial results of a empirical prediction model based on them. While still limited by the fundamentally complex physics behind the origins of the solar wind and how its structure develops in the magnetic photosphere and expands into the heliosphere, our model provides a near continuous range of solar wind speeds and composition quantities that are simply estimated from the inferred structure of the chromosphere. We suggest that the derived quantities may provide input to other, more sophisticated, prediction tools or models such as those to study Coronal Mass Ejections (CME) propagation and Solar Energetic Particle (SEP) generation.

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Sun-as-a-Star Abstracts

Sun-as-a-Star Spectrum Variations 1974-2006

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We have observed selected Fraunhofer lines, both integrated over the Full Disk and for a small circular region near the center of the solar disk, on 1215 days for the past 30 years. **Full Disk results:** *Chromosphere:* Ca II K 3933Å nicely tracks the 11 year magnetic cycle based on sunspot number with a peak amplitude in central intensity of ~37%. The wavelength of the mid-line core absorption feature, called K3, referenced to nearby photospheric Fe, displays an activity cycle variation with an amplitude of 3 mÅ. The separation of the K2 red and blue emission features has increased during the 1976-2006 period of our program. Other chromospheric lines such as He I 10830Å, Ca II 8542Å, Hα , and the CN 3883Å bandhead track Ca II K intensity with lower relative amplitudes. *Low photosphere:* Temperature sensitive CI 5380Å appears constant in intensity to 0.2%. *High photosphere:* The cores of strong Fe I lines, Na D1 and D2, and the Mg I b lines, present a puzzling signal perhaps indicating a role for the 22 y Hale cycle. Solar minimum around 1985 was clearly seen, but the following minimum in 1996 was missing. This anomalous behavior, which is not seen in comparison atmospheric O_2, requires further observations and theoretical inquiry. **Center Disk results:** Both Ca II K and C I 5380Å intensities are constant, indicating that the basal quiet atmosphere is unaffected by cycle magnetism within our observational error. A lower limit to the Ca II K central intensity atmosphere is 0.040. This possibly represents conditions as they were during the Maunder Minimum. Converted to the Mt Wilson S-index (H+K index) the Sun Center Disk is at the lower activity limit for solar-type stars. The wavelength of Ca II K3 varies with the cycle by 6 mÅ, a factor of 2X over the full disk value. This may indicate the predominance of radial motions at Center Disk. This is not an effect of motions in plages since they are absent at Center Disk. This 11 y variation in the center of chromospheric lines could complicate the radial velocity detection of planets around solar-type stars.

An appendix provides instructions for URL access to both the raw and reduced data.

To appear in ApJ March 10, 2007n 2 issue.

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For preprints via ftp or WWW: http://arXiv.org/abs/astro-ph/0612554

Comparing Different Approaches to Model the Rotational Modulation of the Sun as a Star

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The space missions MOST, COROT and Kepler are going to provide us with high-precision optical photometry of solar-like stars with time series extending from tens of days to several years. They can be modelled to obtain information on stellar magnetic activity by fitting the rotational modulation of the stellar flux produced by the brightness inhomogeneities associated with photospheric active regions. The variation of the total solar irradiance provides a good proxy for those photometric time series and can be used to test the performance of different spot modelling approaches. We test discrete spot models as well as Maximum Entropy and Tikhonov regularized spot models by comparing the reconstructed total sunspot area variation and longitudinal distributions of sunspot groups with those actually observed in the Sun along activity cycle 23. Appropriate statistical methods are introduced to measure model performance versus the timescale of variation. The Maximum Entropy regularized spot models show the best agreement with solar observations reproducing the total sunspot area variation on time scales ranging from a few months to the activity cycle, although the model amplitudes are affected by systematic errors during the minimum and the maximum activity phases. The longitudinal distributions derived from the models compare well with the observed sunspot group distributions except during the minimum of activity, when faculae dominate the rotational modulation. The resolution in longitude attainable through the spot modelling is $\sim 60°$, on average. The application of the Maximum Entropy modelling to solar analogues will provide us with a quite detailed picture of their photospheric magnetic activity that can be the base for comparative and evolutionary studies of solar-like magnetic activity and irradiance variations.

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Low-Mass and Substellar Abstracts

Infrared Observations of a Mid-L Dwarf with Strong Hα Emission

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We present *Spitzer*/IRAC observations of the L5 dwarf, 2MASSI J1315309 -264951 (2M1315). This ultracool dwarf is known to display strong emission in the Hα line. The SED for this object does not show any IR excess, that would indicate the presence of an accretion disk. Although the IRAC colors for 2M1315 are consistent with other L dwarfs, they seem to be redder by ~0.1 mag compared to the other L5 dwarfs, and more like the late-type L dwarfs. The existing six epochs of spectroscopy suggest that the emission in Hα is not persistent, but shows long-term variability between a flare value of ~100 $\AA$ and a quiescent value of ~25 $\AA$. Chromospheric activity seems to be the most likely cause, which is also indicated by the detection of Na I D lines in emission (Fuhrmeister et al.). We have measured a proper motion of $0.79'' \pm 0.06''$/yr, that corresponds to a tangential velocity of ~81 km/s, at a distance of ~22 pc. The high V_{tan} for this object suggests an old age. Evolutionary models indicate lower limits of 3.3 Gyr (Chabrier et al.) or 1.4 Gyr (Burrows et al.) for this magnetically active L dwarf to be a stable hydrogen- burning star. There seem to be no observational differences between this old L dwarf that has Hα emission and the other field L dwarfs without it.

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The Late-T Dwarf Companion to the Exoplanet Host Star HD 3651: A New Benchmark for Gravity and Metallicity Effects in Ultracool Spectra

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We present near-IR (1.0–2.5 micron) photometry and spectroscopy of HD 3651B, the low-luminosity, wide-separation (480 AU) companion to the K0V exoplanet host star HD 3651A. We measure a spectral type of T7.5±0.5 for HD 3651B, confirming both its substellar nature and the fact that wide-separation brown dwarfs and giant planets can co-exist around the same star. We estimate an age of 3–12 Gyr for the primary star HD 3651A and find that it is ≈3× older than the K4V star Gl 570A (≈1–5 Gyr), the host star of the T7.5 dwarf Gl 570D. We derive a bolometric luminosity of $\log(L_{bol}/L_{\odot}) = -5.58 \pm 0.05$ for HD 3651B and infer an effective temperature of 780–840 K and a mass of 40–72 M_{Jup}; the luminosity and temperature are among the lowest measured for any brown dwarf. Furthermore, HD 3651B belongs to the rare class of substellar objects that are companions to main-sequence stars and thus provides a new benchmark for studying very low-temperature objects. Given their similar temperatures ($\Delta T_{\rm eff} \approx 30$ K) and metallicities (Δ[Fe/H] ≈ 0.1 dex) but different ages, a comparison of HD 3651B and Gl 570D allows us to examine gravity-sensitive diagnostics in ultracool spectra. We find that the expected signature of HD 3651B's higher surface gravity due to its older age, namely a suppressed K-band flux relative to Gl 570D, is not seen. Instead, the K-band flux of HD 3651B is enhanced compared to Gl 570D, indicative of a younger age. Thus, the relative ages derived from interpretation of the T dwarf spectra and from stellar activity indicators appear to be in discord. One likely explanation is that the K-band fluxes are also very sensitive to metallicity differences. Metallicity variations may be as important as surface gravity variations in causing spectral differences among field late-T dwarfs.

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For preprints via WWW: http://arxiv.org/abs/astro-ph/0701111

XEST Abstracts

Editor's Note: The abstracts below for the XMM-Newton Extended Survey of the Taurus Molecular Cloud (XEST) are being cross-listed with the *Star Formation Newsletter*. Additional XEST abstracts can be found in the Sept. - Dec. 2006 issues of *Coolnews*.

The X-ray Activity–Rotation Relation of T Tauri Stars in Taurus-Auriga

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The Taurus-Auriga star-forming complex hosts the only population of T Tauri stars in which an anticorrelation of X-ray activity and rotation period has been observed. We have used *XMM-Newton*'s European Photon Imaging Cameras to perform the most sensitive survey to date of X-ray emission (0.3-10 keV) from young stars in Taurus-Auriga. We investigated the dependences of X-ray activity measures – X-ray luminosity, $L_{\rm X}$, its ratio with the stellar luminosity, $L_{\rm X}/L_\star$, and the surface-averaged X-ray flux, $F_{\rm XS}$ – on rotation period and compared them with predictions based solely on the observed dependence of $L_{\rm X}$ on a star's $L_\star$ and whether it is accreting or not. We tested for differences in the distributions of $L_{\rm X}/L_\star$ of fast and slow rotators, accretors and non-accretors, and compared the dependence of $L_{\rm X}/L_\star$ on the ratio of the rotation period and the convective turnover timescale, the Rossby number, with that of late-type main-sequence stars. We found significant anticorrelations of $L_{\rm X}$ and $F_{\rm XS}$ with rotation period, but these could be explained by the typically higher stellar luminosity and effective temperature of fast-rotators in Taurus-Auriga and a near-linear dependence of $L_{\rm X}$ on $L_\star$. We found no evidence for a dependence of $L_{\rm X}/L_\star$ on rotation period, but for accretors to have lower $L_{\rm X}/L_\star$ than non-accretors at all rotation periods. The Rossby numbers of accretors and non-accretors were found to be the same as those of late-type main-sequence stars showing saturated X-ray emission. We conclude that non-accreting T Tauri stars show X-ray activity entirely consistent with the saturated activity of late-type main-sequence stars. Accreting T Tauri stars show lower X-ray activity, which cannot be attributed to their slower rotation.

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Upcoming Meeting

The Biggest, Baddest, Coolest Stars

16 - 18 July 2007

Johnson City, TN

Hosted by: East Tennessee State Univ.

Contact: Donald Luttermoser (lutter@etsu.edu)

On the web: http://www.etsu.edu/physics/cool/cool.html

Topics:
Red Giant Stars
Supergiant Stars
Horizontal Branch Stars
Asymptotic Giant Branch Stars
OH/IR Stars
Proto-Planetary Nebulae

In relation to atmospheres, circumstellar envelopes, interiors, evolution, and planets around such objects based on observation (both variability and spectra), modeling and theoretical work. Johnson City is in the extreme northeast region of Tennessee, nestled in the southern Appalachian Mountains. Two other cities neighbor Johnson City, Bristol and Kingsport, which gives this area the name of "The TriCities". These cities are serviced by the TriCity, Tennessee (TRI) regional airport. Weather in July is typically sunny with highs in the low- to mid-80s and lows in the mid-60s. ETSU is primarily an undergraduate institution with an adjacent medical school. The total student population is approximately 12,000 students.

This meeting will be the third in a series of astronomical conferences hosted by ETSU. The previous two were "The Nature and Evolution of Disks Around Hot Stars" (Summer 2004) and "Probing the Distant Universe with Gravitational Waves" (Fall 2005).

Abstract Guidelines

Abstracts for *COOLNEWS* are solicited for papers that have been recently accepted by or submitted to refereed journals, and for recent Ph.D. theses. Abstracts for conference proceedings articles are *not* posted in *COOLNEWS*. The subject matter should pertain directly to cool stars (spectral types F,G,K,M or L), substellar objects, or the sun. Both theoretical and observational abstracts are appropriate.

Abstracts dealing with cool pre-main-sequence (PMS) stars will generally not be included in *COOLNEWS*, since they are already covered by the *Star Formation Newsletter*. Exceptions to this rule will be considered if the subject matter is truly cross-disciplinary. If you wish to submit a cross-disciplinary abstract on PMS stars, then first submit it to the *Star Formation Newsletter*. After doing so, submit the abstract to *COOLNEWS* accompanied by a short e-mail stating that it has already been submitted to the *Star Formation Newsletter*, and summarizing why it will be of interest to the cool star/solar community at large.

A monthly call for abstracts will be issued and abstracts received by the last day of the month will usually appear in the following month's newsletter. Announcements of general interest to the cool star and solar communities may also be submitted for posting in the newsletter. These might include (but are not restricted to) the following: (i) *Job Openings* directed toward cool star or solar researchers, (ii) announcements of *Upcoming Meetings*, (iii) announcements of *Upcoming Observing Campaigns* for which participation is solicited from the community at large, (iv) reviews of *New Books*, and (v) *General Announcements* that provide or request research-related information. Please send all correspondence to the editor at coolnews@jila.colorado.edu. Abstract templates and back issues can be obtained from the COOLNEWS Web-page at

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

*** Please send abstracts in the body of the message and *not* as attachments.***