COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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Stellar Abstracts

Membership and Lithium Abundances of Late-type Stars in NGC 6633

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NGC 6633 is a young, open cluster with a similar age to the Hyades and Praesepe, but lower metallicity. Using a new photometric survey and proper-motion information, a sample of candidate members of NGC 6633 have been observed spectroscopically. Radial velocities have been used to confirm membership for 21 late-type stars including two spectroscopic binaries. By combining the spectroscopy with existing UBV photometry, it is shown that NGC 6633 has a significantly lower metallicity than the Hyades, but not much lower than [M/H]=0.0. The projected equatorial velocities of the cluster members are compared with Hyades rotation data and found to be consistent. The Lithium abundances, determined from the Li I 6708Å line, are indistinguishable from those in the Hyades for F-stars, but show a different pattern of depletion in the cooler stars that can be qualitatively attributed to the lower metallicity. Three early K-stars have log N(Li)> 1.2, whereas only smaller upper limits can be found in the Hyades and Praesepe. Comparison with younger Pleiades cool stars, which have a similar metallicity to NGC 6633, shows that Li depletion apparently occurs in G and K stars while they are on the main-sequence. Standard models, incorporating only convective mixing, under-predict the depletion in both the Hyades and NGC 6633, but match the lower envelope of the Pleiades distribution. These data argue strongly against enhanced interior opacities as a way of increasing Li depletion in the standard models and instead point to extra mixing mechanisms on the main sequence combined with a rotation-dependent Li-depletion inhibition process acting during pre-main-sequence evolution.

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The Local ISM and its Interaction with the Winds of Nearby Late-type Stars

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We present new Goddard High Resolution Spectrograph (GHRS) observations of the Lyman-α and Mg II absorption lines seen toward the nearby stars 61 Cyg A and 40 Eri A. We use these data to measure interstellar properties along these lines of sight and to search for evidence of circumstellar hydrogen walls, which are produced by collisions between the stellar winds and the local interstellar medium (LISM). We were able to model the Lyman-α lines of both stars without hydrogen wall absorption components, but for 61 Cyg A the fit required a stellar Lyman-α line profile with an improbably deep self-reversal, and for 40 Eri A the fit required a very low deuterium-to-hydrogen ratio inconsistent with previous GHRS measurements. Since these problems could be rectified simply by including stellar hydrogen wall components with reasonable attributes, our preferred fits to the data include these components.

We have explored several ways in which the hydrogen wall properties measured here and in previous work can be used to study stellar winds and the LISM. In particular, we estimate stellar wind pressures (P_{wind}) from the measured hydrogen wall column densities. These estimates represent the first empirical measurements of wind properties for late-type main sequence stars. The wind pressures appear to be correlated with stellar X-ray surface fluxes, F_X, in a manner consistent with the relation $P_{wind} \propto F_X^{-1/2}$, a relation that is also consistent with the variations of P_{wind} and F_X observed during the solar activity cycle. If this relation can in fact be generalized to solar-like stars, as is suggested by our data, then it is possible to estimate stellar wind properties simply by measuring stellar X-rays. One implication of this is that stellar wind pressures and mass loss rates are then predicted to increase with time, since F_X is known to decrease with stellar age.

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A Large X-ray Flare on HU Virginis

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We present two ROSAT-HRI observations of the RS CVn-type binary HU Virginis (=HD 106225). The first observation covers almost three consecutive rotation cycles of HU Virginis or a total of 26.7 days and an exposure time of 35 ksec. On JD 2,449,544 a long duration flare was detected and observed for 1.5 days. This event was releasing a total energy of $\approx 7.7^{+3.3}_{-1.9} \times 10^{36}$ erg in the 0.1–2.4 keV bandpass. The good coverage of the onset and maximium phase of the lightcurve allowed a detailed comparison with two solar flaremodels. We derived an estimate for the size of the active region which was responsible for the flare. The resulting loopsize is of the order of one stellar radius. One year later, in 1995, HU Virginis was again observed by ROSAT continuously for 8 days and a total exposure time of 69 ksec. The X-ray flux shows variability on time scales shorter than the rotational period.

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Near-Infrared Spectra of Flat-Spectrum Protostars: Extremely Young Photospheres Revealed

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We present new high resolution ($R \simeq 21,000$) near-infrared ($\lambda = 2\mu$m) spectroscopic observations of a sample of flat-spectrum and Class II young stellar objects in the ρ Ophiuchi dark cloud. Our observations of the flat-spectrum sources are the first to reveal details about the atmospheres of objects so young that they are still in the protostellar stages of early stellar evolution. The flat-spectrum objects exhibit molecular (CO) and atomic (Na, Sc, Si) line shapes which are consistent with those expected for rotating stellar photospheres. No clear spectroscopic signatures of line formation in Keplerian circumstellar disks are found. The 2.294 μm $\nu = 0-2$ CO spectra show that the flat-spectrum objects are rotating more rapidly ($\langle v\sin i \rangle \simeq 26$ km s^{-1}) than the Class II pre-main-sequence stars in our sample ($\langle v\sin i \rangle \simeq 12$ km s^{-1}). Analysis of the relative strengths of the atomic lines of the two flat-spectrum sources GY21 and VSSG17 indicates that these objects have late spectral types, M0 and M2 (or later), respectively. Their surface

gravities are more similar to those of late-type dwarfs or pre-main-sequence subgiant stars than to those of late-type stellar giants or FU Ori stars. These characteristics can be understood if the absorption lines of flat-spectrum sources arise in stellar (rather than disk) atmospheres that are similar to those of pre-main-sequence subgiant T Tauri stars but are accreting mass from their circumstellar disks at higher rates.

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Editor's Note: The above cross-disciplinary abstract also appeared in The Star Formation Newsletter (No. 59, Aug. 97) and is being cross-listed here since it may be of interest to those studying M-type stars.

A Study of the Chamaeleon Star–forming Region from the ROSAT All–Sky Survey. III. High Resolution Spectroscopic Study

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We present the results of a high–resolution spectroscopic study on some 70 stars, discovered recently on the basis of the ROSAT all–sky survey spread over a wide area in the Chamaeleon star forming region and classified as new weak–line T Tauri stars. We refine the previous spectral type classification, based on low–resolution spectra, and characterize each star in the sample according to the Hα line profile.

We use the strength of Li I 6708, compared to Pleiades stars of the same spectral type, as a youth discriminator in order to recognize *bona-fide* pre-main sequence stars. According to the adopted "lithium criterion", more than 50% of the stars in our sample are confirmed to be truly young, PMS stars (most having age less than 5×10^6 yr), while the remaining part seems mostly composed by active, young, foreground main–sequence stars (possibly Pleiades–like), which contaminate the original sample. We confirm the existence of some very young stars far from the main Chamaeleon clouds, while we do not find clear evidence for the presence of post-T Tauri stars in our sample.

We find that 5 stars in the sample are spectroscopic binaries and 1 is a spectroscopic triple system. We derive radial and rotational velocities for all the stars in sample and analyse their distributions for different spectral type intervals. The radial velocity distribution shows a clear peak at about 15 km s^{-1}, which coincides with the radial velocity of stars and gas in the Cha I cloud. However, the velocity dispersion of the weak–line T Tauri stars appears much broader and, possibly, a second peak is present around 16–18 km s^{-1}. A clear segregation in radial velocity is observed between the strong–lithium and the weak–lithium stars, with the former showing radial velocities which, in most cases, fall in the interval 12<RV [km/s] < 18, consistent with the radial velocity peak observed for the Cha I dark cloud, and the latter having somewhat different and more widely spread radial velocities. Some strong–lithium stars having radial velocities outside the aforementioned interval might be unrecognized spectroscopic binaries, but they may also be considered good candidates to be run-away T Tauri stars. The $v \sin i$ distribution of the confirmed WTTS is found to resemble very closely that of other pre-ROSAT PMS stars. We conclude that the whole star forming region has a common origin, possibly related to the impact of a high–velocity cloud with the galactic plane.

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Differential Rotation and Meridional Flow for Fast-Rotating Solar-type Stars

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Observations indicate that normalized surface differential rotation *decreases* for fast rotating stars: $|\Delta\Omega|/\Omega \propto \Omega^{-0.3}$. An *increase* of $|\Delta\Omega|/\Omega$ is provided, however, by the present-day Reynolds stress theory of differential rotation in stellar convection zones without inclusion of meridional flow. We compute both the pole-equator difference of the surface angular velocity and the meridional drift for various Taylor numbers to demonstrate that the inclusion of meridional flow into the computations for fast rotation yields a systematic reduction of the resulting differential rotation. Our model's adiabatic and density-stratified convection zone with stress-free surfaces and a thickness of 0.3 stellar radii yields the relation $|\Delta\Omega|/\Omega \propto \Omega^{-(0.15\ldots0.30)}$ for stars with faster rotation than the Sun in agreement with previous observations. If the Coriolis number is varied instead of the Taylor number, we find a maximum differential rotation of 20%. For stars with fast rotation, exponents up to $n' \simeq 0.4$ are found. All rotation laws exhibit super-rotating equators.

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Analysis of Infrared Lunar Occultation Observations of Carbon Star TX Piscium: Close Duplicity and Brightness Distribution across the Disk

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We present the results of the analysis of three lunar occultation light curves for carbon star TX Psc, observed by A.Richichi et al. (1995) in near infrared at 1992-1993. The strip brightness distributions, restored by the use of the regularization method, show that this star is double with the angular distance of components $0.''052 \pm 0.''002$ at position angle $241° \pm 3°$ and the magnitude difference $3.^m5 \pm 0.^m5$ on wavelength 2.2 micrometre. The brightness distributions as well as the spectrophotometry data not confirm the presence of a circumstellar dust shell which radiated light in near infrared. The search for radial brightness distributions for the bright component TX Psc A has been carried out in a compact set of non-negative bounded monotonic functions, assuming a circular symmetri of stellar images. The restored radial brightness distributions across the disk of TX Psc A agree with the model fiting data on the angular diameter and are coincident qualitatively with the results of the extended atmosphere model calculations for red giants.

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Library of High-resolution UES Echelle Spectra of F, G, K and M Field Dwarf Stars

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We present a library of Utrecht echelle spectrograph (UES) observations of a sample of F, G, K and M field dwarf stars covering the spectral range from 4800 Å to 10600 Åwith a resolution of 55000. These spectra include some of the spectral lines most widely used as optical and near-infrared indicators of chromospheric activity such as Hβ, Mg I b triplet, Na I D_1, D_2, He I D_3, Hα, and Ca II IRT lines, as well as a large number of photospheric lines which can also be affected by chromospheric activity. The spectra have been compiled with the aim of providing a set of standards observed at high-resolution to be used in the application of the spectral subtraction technique to obtain the active-chromosphere contribution to these lines in chromospherically active single and binary stars. This library can also be used for spectral classification purposes. A digital version with all the spectra is available via ftp and the World Wide Web (WWW) (http://www.ucm.es/OTROS/Astrof/fgkmsl/UESfgkmsl.html) in both ASCII and FITS formats.

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Spectroscopy and Eclipse-mapping of the Mass-exchanging Binary Star V361 Lyr

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We present the first spectroscopic investigation of the short-period ($P = 0.309614$ day) mass-exchanging binary system V361 Lyr. From observations over two complete orbits, we show that the system is double-lined, with the stars having minimum masses of $m_1 \sin^3 i = 1.25 \pm 0.03$ $M_\odot$ and $m_2 \sin^3 i = 0.87 \pm 0.03$ $M_\odot$. The mass ratio $m_2/m_1 = 0.69 \pm 0.02$ and the projected semi-major axis of the relative orbit is $a \sin\ i = 2.47 \pm 0.05$ $R_\odot$. The spectral type of the primary component is estimated to be F8-G0. The H α line profile clearly shows two absorption components when the system is at its brightest and bluest stage, around orbital phases 0.35-0.45 . The published V and I light curves (Kaluzny 1990, 1991) are analysed with LIGHT2 to show that the primary component ($T = 6200$K) fills its Roche lobe, whilst the secondary ($T = 4500$K) is detached and fills $\approx 57\%$ of the available Roche volume. Eclipse maps of both stellar surfaces are derived via DOTS (Collier Cameron 1997) from light curves obtained in 1988, 1989, and 1992. These show that the secondary has a persistent elongated hot structure on its equator with an estimated temperature of $10,000$K that is consistent with the expectations of a theoretical mass transfer stream leaving the primary at its inner Lagrangian point and falling on to the secondary. The accretion luminosity of ≈ 0.5 $L_\odot$ from that impacting stream, as estimated from the observed decrease in orbital period and the derived stellar masses, is about twice the luminosity of the structure inferred from the light curves and the surface-image reconstructions. The eclipse maps for the primary illustrate small changes in the *cool* spot structures that are typical of magnetic activity observed in other rapidly-rotating solar-type stars that are single or are members of binary systems (e.g. AB Dor, XY UMa). This model for V361 Lyr predicts successfully the phase-dependent variations observed in the H α line.

The properties of this mass-exchanging semi-detached binary are compared to the near-contact and the contact systems of the W UMa type for the purpose of establishing whether or not it represents the short-lived phase of evolution into contact for the first time, or the broken-contact stage of a thermal-relaxation oscillation. The derived locations of *both* components on the ZAMS would favour the former interpretation. V361 Lyr is reddened by $E(B-V) = 0.43$ and lies at a distance of 520 ± 40 pc.

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New Rotation Periods in the Pleiades: Interpreting Activity Indicators

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We present results of photometric monitoring campaigns of G, K and M dwarfs in the Pleiades carried out in 1994, 1995 and 1996. We have determined rotation periods for 18 stars in this cluster. In this paper, we examine the validity of using observables such as X-ray activity and amplitude of photometric variations as indicators of angular momentum loss. We report the discovery of cool, slow rotators with high amplitudes of variation. This contradicts previous conclusions about the use of amplitudes as an alternate diagnostic of the saturation of angular momentum loss. We show that the X-ray data can be used as observational indicators of mass-dependent saturation in the angular momentum loss proposed on theoretical grounds.

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Solar Abstracts

Small-scale Topology of Solar Atmosphere Dynamics I. Wave Sources and Wave Diffraction

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We study the small-scale topology of dynamical phenomena in the quiet-sun internetwork atmosphere, using short-duration Fourier analysis of high-resolution filtergram sequences to obtain statistical estimates for the co-location probability of different fine-structure elements and wave modes.

In this initial paper we concentrate on the topology of short-duration Fourier amplitude maps for the photosphere and the simultaneously observed overlying chromosphere. We find that these maps portray a complex mix of global modes and locally excited waves which necessitates a statistical approach. Various aspects including mesoscale patterning indicate the presence of subsurface wave sources and of subsurface wave diffraction by convective inhomogeneities.

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Small-scale Topology of Solar Atmosphere Dynamics II. Granulation, K2v Grains and Waves

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We continue studying the small-scale topology of dynamical phenomena in the quiet-sun internetwork atmosphere through statistical estimation of the co-location probability of different fine-structure elements and wave modes. In this paper we chart spatial alignments between the granular brightness structuring of the photosphere, Ca II K_{2v} brightness patterns in the chromosphere, and wave amplitude patterns in both regimes as a function of time delay between the occurrences of the various features. These charts confirm the presence of excess 2–4 min waves above dark intergranular lanes, the absence of excess 5 min waves above bright granules, the absence of expected alignments between photospheric and chromospheric wave patterning, and the broad-band nature of Ca II K_{2v} grain formation. In addition, they show significant alignments at large time delays that seem to be regulated by mesoscale patterning and pattern migration.

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Formation of Li I Lines in Photospheric Granulation

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The possibility of significant systematic errors due to the use of 1D homogeneous atmospheres in lithium-abundance determinations of cool stars motivates a study of non-local-thermodynamic-equilibrium (NLTE) effects on Li I line formation in a 3D solar-granulation simulation snapshot. The NLTE effect on the equivalent width of the 671 nm resonance line is small in 1D models or in integrated light from the granulation model. The line-strength variations over the granulation pattern are however markedly different in NLTE compared to LTE – observations of this may provide diagnostics to NLTE effects. The effects of horizontal photon exchange found in the granulation model are moderate and due entirely to bound-bound processes, ultraviolet overionization is unimportant.

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Chromospheric Evidence for Magnetic Reconnection

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We study the decay phase of an M2.6 flare, observed with ground based instruments at NSO/Sac Peak and with the cluster of instruments onboard *Yohkoh*. The whole set of chromospheric and coronal data gives a picture consistent with the classical Kopp-Pneuman model of two-ribbon flares. We clearly witness new episodes of coronal energy release, most probably due to magnetic reconnection, during the decaying phase of the flare. Within the newly created chromospheric ribbons, we identify several small kernels, footpoints of magnetic loops involved in the flare, where energy is probably deposited by a conduction front from coronal sources. The presence of a source (T_e=22 MK, and EM=$5.\times10^{48}$ cm^{-3}) thermally emitting in the 14-23 keV energy band confirms this hypothesis.

A new, interesting observational result is given by the measure of chromospheric downflows in different parts of the flaring kernels. For all the cases examined, we find a stronger downflow at the outer edge of the flaring structure. The flows have amplitude of tens of km/s, over regions only a few arcsec across, and seem to decrease when the flaring kernels slow their motion on the solar surface and fade away. We believe that these downflows directly map the outer boundary magnetic field lines of the reconnecting loops, as predicted in recent reconnection models that take into account explicity the effects of heat conduction. The flows represent the chromospheric counterpart of coronal features observed in soft X-ray such as cusp-like structures and the temperature stratification in flaring loop systems. The observed amplitude of these chromospheric flows could be an important constraint for quantitative modelling of coronal reconnection mechanisms and their effects on the lower solar atmosphere.

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Alfvénic Fluctuations in Fast and Slow Solar Winds

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We compute properties of Alfvénic fluctuations within a wide frequency range (i.e., 10^{-6} s^{-1} $\leq f \leq 10^{-2}$ s^{-1}) in both high– and low–speed magnetized radial solar winds. In particular, the radial and frequency variations of the normalized cross helicity σ_c, the Alfvén ratio $\mathcal{R}_A$, and other relevant quantities associated with Alfvénic fluctuations are presented and analyzed. Because of the existence of the Alfvén critical radius r_A and a characteristic frequency f_c for a given magnetized solar wind profile, continuous reflection effects are clearly manifest at frequencies lower than several times f_c. Since outward propagating fluctuations which many authors consider Alfvénic fluctuations have been detected in the high–latitude solar wind (which is fast and steady), such continuous reflection effects in the low–frequency end of the fluctuation spectrum may be found in the Ulysses data. In order to strengthen our case, comparisons are carried out between our theoretical results and previous data analyses of observations from the Helios 1 and 2 spacecraft in the radial range of 0.29 AU $\leq r \leq$ 1.0 AU. Stronger evidence for continuous reflection effects of low–frequency Alfvénic fluctuations is found in the high–speed solar wind close to the Sun than in the low–speed solar wind in general.

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Accurate Determination of Electron Densities in Active and Quiescent Prominences: the Mid-Infrared Advantage

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We have analyzed all lines in the MIR (8 to 20 micron) spectra of a quiescent and two time-frames of an active prominence. In the quiescent prominence in addition to those found by Zirker(1985), we have identified a higher excitation hydrogen line and two helium recombination lines. Accounting for instrumental broadening, we can further separate out the Doppler and the Stark contributions to the line width. The former yields maximum temperatures of 6200K, 34000K and 12000K and the latter electric field strengths of 7, 17, and 10 V/cm for the above prominences respectively. We show that these electric fields when divided by 2.2 are equal to the normal electric field in Holtsmark's quasi-static Stark broadening theory. Hence we obtain electron densities of N_e=2.4(0.3), 9.1(1.2), and 5.5(0.6) in units of 10^{10} cm^{-3} respectively. Using the same assumptions made by Zirker, namely, (1) the strongest line (7-6) is optically thin, (2) the population of the lower level(n=6) is determined by direct radiative recombination and photo-ionization, (3) the equality of proton and electron densities, and (4) the thickness of the prominence is at least 10^8 cm, we derive a new inequality, $N_e \leq 1.83 \times 10^8 T^{0.75} e^{-2195/T}$. Substituting our maximum temperatures into the RHS, we find upper bound N_e values of 9, 43 and 30 in the same units as above. These upper bound values are comfortably higher than our measurement, unlike those of Zirker's derived from the same set of assumptions. We have also observed the helium recombination spectrum which has been postulated by Tandberg-Hanssen as one of three possible ways of equilibrating the triplet/singlet ratio. Surprisingly, it is present in the quiescent as well as in the active prominence. We show that no meaningful values can be found for the turbulent velocities by combining the helium with the hydrogen line widths.

Submitted to Solar Physics

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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. The subject matter should pertain directly to cool stars (spectral types F,G,K, or M) or the sun. Both theoretical and observational abstracts are appropriate. Abstracts dealing with cool pre-main-sequence 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. 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` .