COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

No. 14 — November 1996 Editor: Steve Skinner (coolnews@jila.colorado.edu)

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Stellar Abstracts

Silicate Feature Variation in LPV Stars I. Initial Observations

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We report new mid-infrared spectra of five bright, long period variable stars, and related objects, obtained at the Wyoming Infrared Observatory with Denver University's medium resolution CAESR instrument. The data, when combined with LRS spectra from IRAS, show variation of the silicate feature with phase of the LPV. We perform a calculation for impingement time of the shock on the circumstellar dust shell to demonstrate that this variation could be due to a shock-shell interaction.

Accepted by ApJ

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ROSAT and AB Doradus: The First Five Years

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Five and a half years of data from an extensive ROSAT X–ray monitoring program devoted to the young K–star AB Dor are presented. Begun in mid–1990, this program is aimed at the study of the long–term behaviour of coronal flux levels in this very active star. We compare the X–ray data with 17 years of V–band brightness monitoring that shows a 10–year decline between 1978 and 1989 and a subsequent rise phase. In contrast, the X–ray flux, which is very variable on time scales of minutes to weeks, exhibits no pronounced long–term trend over the 5 1/2 years of the program. This supports the concept of a saturated corona. Making use of the ROSAT all–sky survey data and data from the most extensive among the available pointed observations we also discuss the short–term variablity in relation to the rotational time scale. We find evidence for a partial rotational modulation of the X–ray flux implying structural inhomogeneities in this saturated corona.

Accepted by A&A

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The Hα Behavior in Bright Giant Stars

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We report high resolution spectroscopic observations of the Hα line profile for a sample of 32 bright giant stars with spectral type between F3 II and G5 II. By studying the link between the Hα behavior and the stellar rotation in such class of luminosity we have found no clear evidence that the rotational discontinuity established around F9 II is related with the Hα profiles. No emission features, neither time variations or asymmetries on the Hα line profiles have been detected for the bright giants analysed in the present work.

Accepted by A&A

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Properties of Sun-like Stars with Planets: ρ^1 Cnc, τ Boö, and υ And

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Planets have been reported orbiting the sun-like stars ρ^1 Cnc, τ Boö, and υ And based on low-amplitude radial-velocity variations. We have derived information on the first two stars from analysis of spectra as well as parallel records of high-precision Strömgren b and y photometry and Ca II H+K fluxes. In the case of ρ^1 Cnc, the upper limit (peak-to-peak) of non-detection of photometric variability at the orbital period is $\Delta y \sim 0.0004$ mag. The possibility of a planetary transit cannot be ruled out completely from the photometric data. Variations of the Ca II fluxes suggest a rotation period of $\sim$ 42 days, in agreement with the inferred $v \sin i \sim 2$ km s^{-1}. The age of ρ^1 Cnc is $\sim$ 5 Gyr, based on its average Ca II flux and a relation between Ca II flux and age.

The star τ Boö, unlike the other reported solar-type stars with planets, is relatively young ($\sim$ 2 Gyr). Despite its young age, it is photometrically non-variable at the orbital period with an amplitude of $\Delta(b+y)/2 \sim 0.0004$ mag (peak-to-peak); however, small amplitude inter-seasonal variability is seen. No planetary transits were found in the photometry, which limits the inclination of the planet's orbital plane to the Earth's line of sight to $< 83°$ (where $90°$ is co-planar). The Ca II record shows a weakly-significant rotation period near 3.3 days, coincident with the orbital period of the companion. The Ca II record also shows a period of 116 days that has persisted for 30 years and is not seen in the photometric record. The persistence and timescale of this Ca II variation means that it has no counterpart in sun-like magnetic activity. The amplitude of the reflex velocity of the parent star ($\sim$ 450 m s^{-1}) is much larger than radial velocity perturbations expected from the presence of either surface inhomogeneities or line-bisector variations. Thus, the anticipated perturbations from those stellar effects do not refute the inference of reflex velocities.

We have few Ca II flux measurements for υ And. Its age and rotation period are estimated to be $\sim$ 5 Gyr and 12 days, respectively. Our results for ρ^1 Cnc and τ Boö are consistent with the explanation of planets as the cause of the velocity variations.

Accepted by ApJ (Letters)

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Stellar Active Region Evolution I – Estimated Lifetimes of Chromospheric Active Regions and Active Region Complexes

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The lifetimes of chromospheric active regions and active region complexes ("active longitudes") for 35 lower main sequence stars observed at Mount Wilson Observatory are estimated from the relative distribution of pooled variance at different time scales. The time scale of active region evolution (i.e., the lifetime of large active regions) is approximately 50 days, while the lifetime of active region complexes is on the order of 1 year. These estimates can be used to clarify the contribution of active regions to variance in short-term (i.e., < 1 yr) time series data. Previously unpublished mean rotation periods are documented for several stars.

Accepted by Solar Physics

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Stellar Active Region Evolution II – Identification and Evolution of Variance Morphologies in Ca II H+K Time Series

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The relative distribution of pooled variance computed at various time scales for the records of chromospheric activity has been calculated for approximately 100 stars observed at Mount Wilson Observatory. As shown in Paper I, analysis of the pooled variance provides a technique for estimating the lifetimes of stellar active regions and their influence on chromospheric time series used for determining rotation and activity cycle periods. Pooled variance diagrams may be divided into three morphological types which depend to a large extent on a star's mean level of chromospheric activity (i.e., age) and $B - V$ color (i.e., mass), and possibly depends on star's evolutionary state.

Accepted by Solar Physics

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Coronal Properties of Nearby Old Disk and Halo dM Stars

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ROSAT X-ray (PSPC) and EUV (WFC) observations of a sample of 12 nearby Halo and Old-Disk low mass stars have been analyzed to determine their emission levels, properties of their coronal spectra and to characterize their temporal variations on time scales from hours to ten years. The light curves of the old-disk stars of our sample with the highest count statistics, show that variability of a factor two on a time scale of a few thousands of seconds is a common property of old-disk stars. The coronal emission of GJ 191, the only halo star with enough counts to make

the time analysis feasible, shows significant variations on a time scale of six months.

The time resolved spectral analysis of the most intense stars shows that their coronal emission is consistent with a two temperature model with (approximately) constant values of the temperatures along the entire observation, while the observed variability can be explained by changes in their emission measure distributions. We find that the emission measures of the two components change coherently during the observations.

For all ten detected stars we have computed hardness ratio and X-ray luminosity. While our old-disk stars fit well in the body of the distribution outlined by a complete volume limited sample of dM and dK stars within 7 pc (Schmitt et al. 1995), the halo stars tend to occupy the softest and weakest envelope defined by population I low-mass stars.

Accepted by A&A

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X-Ray Spectroscopy of Stellar Coronae: History - Present - Future

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Since in 1948 X-rays were detected from the solar corona, stellar coronae were among the first predicted non-solar X-ray sources. However, because of their relatively low X-ray luminosity, the first non-solar stellar corona was detected in X-rays not until 1974 - twelve years after the discovery of the first non-solar X-ray source. After the 1980s with the advent of sensitive X-ray imaging instruments on board the *EINSTEIN*, *EXOSAT*, and later the *ROSAT* observatories, the study of stellar coronae has become a vastly growing field of research. These X-ray observations have demonstrated that X-ray emitting coronae are a common feature among stars on the cool side of the Hertzsprung-Russell diagram, with the probable exception of single very cool giant and supergiant stars and A-type dwarfs. The instruments on board these satellites provided for the first time a taste of what can be achieved with X- ray spectroscopy and with the advent of the *EUVE* (1992) and *ASCA* (1993) detailed spectroscopy of stellar coronae in the EUV and X-ray regimes has gotten off to a real start. The observations have permitted the identification of coronal material at different temperatures whose existence relates to a range of possible magnetic loop structures in the hot outer atmospheres of stars. The higher spectral resolution of the next generation of spectrometers aboard NASA's *AXAF* (1998), ESA's *XMM* (1999), and the Japanese *ASTRO-E* (2000) will improve the determination of coronal temperature structure, abundances, and densities from which loop geometries can be derived and will enable velocity diagnostics. This paper reviews our present knowledge of observational stellar X- ray spectroscopy up to *EUVE* and *ASCA* and briefly discusses the perspectives for coronal diagnostics offered by *AXAF*, *XMM*, and *ASTRO-E*.

Dedicated to Cornelis de Jager at his 75th birthday.

"Curiosity is the driver for a discovery, rather than the official expectation."

Accepted by Solar Physics

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Asteroseismology from Equivalent Widths: A Test of the Sun and Methodologies for Stellar Observations

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Kjeldsen *et al.* (1995) reported a probable detection of solar-like, low-amplitude, p-mode oscillations of η Bootes using equivalent width measurements from low-resolution spectra of the hydrogen Balmer lines. Here we explore the usefulness of this technique on a variety of telescopes and spectrographs. Observations of integrated sunlight over a 4-hour period using the McMath-Pierce solar telescope reveal the 5-minute solar oscillations at the expected amplitude. Data from the Kitt Peak coudé feed and 2.1-m telescopes are used to develop observing and data reduction techniques, such as a synchronized timing system to maintain evenly spaced temporal samples, improved CCD readout efficiencies to increase the duty cycle of the observations, and simulations of the probability of a detection as a function

of observing run length.

Submitted to PASP

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Evaluating Possible Heating Mechanisms Using the Transition Region Line Profiles of Late-Type Stars

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Our analysis of HST/GHRS spectra of late-type stars shows that the Si IV and C IV lines formed near 10^5 K can be decomposed into the sum of two Gaussians, a broad component and a narrow component. We find that the flux contribution of the broad components is correlated with both the C IV and X-ray surface fluxes. For main sequence stars, the widths of the narrow components suggest subsonic nonthermal velocities, and there appears to be a tight correlation between these nonthermal velocities and stellar surface gravity ($\xi_{\rm NC} \propto g^{-0.68\pm0.07}$). For evolved stars with lower surface gravities, the nonthermal velocities suggested by the narrow components are at or just above the sound speed. Nonthermal velocities computed from the widths of the broad components are always highly supersonic. We propose that the broad components are diagnostics for microflare heating. Turbulent dissipation and Alfvén waves are both viable candidates for the narrow component heating mechanism.

A solar analog for the broad components might be the "explosive events" detected by the HRTS experiment. The broad component we observe for the Si IV λ1394 line of α Cen A, a star which is nearly identical to the Sun, has a FWHM of 109 ± 10 km s^{-1} and is blueshifted by 9 ± 3 km s^{-1} relative to the narrow component. Both of these properties are consistent with the properties of the solar explosive events. However, the α Cen A broad component accounts for 25 ± 4% of the total Si IV line flux, while solar explosive events are currently thought to account for no more than 5% of the Sun's total transition region emission. This discrepancy must be resolved before the connection between broad components and explosive events can be positively established.

In addition to our analysis of the Si IV and C IV lines of many stars, we also provide a more thorough analysis of all of the available GHRS data for α Cen A (G2 V) and α Cen B (K1 V). We find that the transition region lines of both stars have redshifts almost identical to those observed on the Sun: showing an increase with line formation temperature up to about $\log T = 5.1$ and then a rapid decrease. Using the O IV] lines as density diagnostics, we compute electron densities of $\log n_e = 9.65 \pm 0.20$ and $\log n_e = 9.50 \pm 0.30$ for α Cen A and α Cen B, respectively.

Accepted by ApJ

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Discovery of Two Short-period Eclipsing Binaries with Active Components

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We present high-precision UBV(RI)$_c$ photometry and ROSAT X-ray light curves for the visual multiple systems HD 9770 and HD 195434. The optical photometry revealed that in both systems one component is a very short-period eclipsing binary showing also BY Dra-type variability. In particular, HD 9770 contains the active star with the shortest period known to date, while HD 195434 is probably a halo population or an old disk star. We have computed accurate orbital periods, deduced approximate physical parameters, spectral classification, distances and X-ray luminosities and identified which component of each visual system is responsible for the optical variability. Furthermore, we find that both systems are variable in X-rays, but no correlation with the optical variability is seen, and confirm the existence of a good correlation between L$_{bol}$ and L$_X$ for this type of stars.

Accepted by A&A

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Lithium in Very Low–Mass Stars in the Pleiades

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High-resolution Keck Telescope echelle observations from 630 nm to 850 nm of seven Pleiads with spectral types from M5 to M6.5 reveal rather rapid rotation, with an average v sin i of 52 km/s, and chromospheric activity in Hα emission. The activity in these stars is not any stronger than that of other Pleiades low-mass stars, despite the expected high contrast of Hα with their cool photospheres and their rapid rotation. This shows that the "levelling off" of Hα equivalent widths previously noted in low-mass stars in young clusters is not related to the conventional rotation-activity connection.

None of the stars previously categorized as brown dwarf candidates have lithium signatures in their spectra. They are, therefore, very low mass stars and not brown dwarfs. However, two stars, HHJ 339 and HHJ 430, 1 and 2 magnitudes above the Pleiades zero-age main sequence, do show abosrption due to Li I at 670.8 nm and in the subordinate feature at 812.6 nm. These two stars are also rotating very rapidly. These facts strongly suggest that these stars are rather young. Their proper motions and radial velocities agree with those measured for the Pleiades as a whole. We discuss various explanations for these stars, none of which are completely satisfactory. In one scenario they represent very late star formation in the Pleiades cluster (implying a huge range in the ages of Pleiads). This seems unpalatable given the lack of matter dense enough to form stars in the Pleiades at present. Another possibility is that these stars formed in a nearby, more recent star formation site and drifted into the Pleiades. Although the cluster recently passed through a clump of young Taurus stars, we do not see how it could "accrete" two of them. In our most feasible explanation, we posit that a cloud which was a member of the "Pleiades Supercluster" recently formed stars, which are now scattered between us and the Pleiades. HHJ 339 and HHJ 430 could be members of this group whose motion has now brought them near the older open star cluster.

Accepted by A.J.

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A Determination of the Coronal Emission Measure Distribution in the Young Solar Analog EK Draconis from ASCA/EUVE Spectra

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We present the results of a coronal differential emission measure (DEM) analysis of the nearby analog of the young Sun, EK Draconis, using data obtained with the ASCA and the EUVE satellites. Various methods (including a clean algorithm, a polynomial fit, a direct inversion method, a genetic algorithm, and a multi-temperature fit) have been applied to reconstruct the DEM between 0.1 and 100 MK. The spectra from the four ASCA detectors and the two spectra from the short-wavelength and the medium-wavelength detectors of EUVE were subject jointly to the algorithms, taking into account both emission lines and continua. All methods converge to a DEM distribution that is essentially bi-modal: We find two significant peaks near 7 MK and near 18 MK with a deep minimum around 10 MK. Little plasma is found at temperatures below 3–4 MK, despite EUVE's sensitivity to this temperature regime. We argue that the DEM distribution seen in EK Dra is induced by the properties of the radiative cooling function of a thermal, optically thin plasma. From an elemental abundance analysis, an Fe abundance of 0.83 $\times$ the corresponding solar photospheric abundance is found, and an abundance of Mg of 1.69 $\times$ solar photospheric, which may indicate for this specific element a FIP effect similar to that found in the solar corona.

Accepted by ApJ

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Stellar Coronal Abundances V: Evidence for the FIP Effect in α Centuri

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We present an analysis of the EUV spectrum of the nearby binary α Cen AB (G2 V, K0 V), observed by the Extreme Ultraviolet Explorer satellite (*EUVE*). Emission measure curves are constructed for elements with high and low first ionization potential (FIP), in order to investigate the coronal composition and determine whether or not a solar-like compositional fractionation mechanism ("FIP effect") is operating in the corona of α Cen. As pointed out in the recent analysis of the α Cen *EUVE* spectra by Mewe et al. (1995), the emission measure distribution is very much like that of the Sun. It peaks at $\log T \sim 6.3$, has a minimum near $\log T \sim 5.5$, and has a slope between these points of approximately 1.75 ($EM \propto T^{\frac{7}{4}}$). The emission measure results for the different elements are not consistent with the underlying photospheric composition and indicate that the low FIP elements are overabundant relative to the high FIP elements by a factor of about 2. This result represents the first evidence of the FIP Effect in solar-like stars with similar activity to that of the Sun.

We also discuss the recently raised possibility that resonant scattering of line radiation might be important in *EUV* stellar spectra like that of α Cen. We conclude that this is unlikely and that the results of global plasma model fitting techniques which have engendered this hypothesis have not taken into account the flux from spectral lines that are missing from current models of plasma radiative loss.

Accepted by ApJ

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Coronal X–Ray Emission of HD 35850: the ASCA View

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We present the analysis of the X–ray data of the young active star HD 35850 obtained with ASCA and ROSAT. Our main goal was to see if there is a difference in the elemental abundances of active stars between young and more evolved objects. A two temperature plasma with subsolar abundances, of the order of $Z = 0.15 - 0.3$, is required to fit the SIS spectra. Similar results are obtained from a ROSAT PSPC observation. A metal abundance value of 0.2 – 0.4 is required in order to fit both the ASCA and ROSAT data together. From a simultaneous SIS0+SIS1 spectral fit, with 2T plasma models and abundances free to vary in non-solar proportions, we find that, besides N, O and Ne for which we find very low values, all other elements have values relative to solar abundances around 0.2–0.3. These subsolar abundances are in line with those typically observed in more evolved, active stars like RS CVn and Algol–type binaries.

The two temperature values required to fit the ASCA SIS spectra are about 0.5 and 1.0 keV. These temperatures, especially the higher one, are lower with respect to the values found for the RS CVn and Algol binaries or for the young star AB Dor, but higher than other single G/K stars. All our data show that this single, late F–type star is actually a very active source, indirectly confirming that this fast rotating star is probably a young object. In the simultaneous fit of the ASCA+ROSAT data, a third temperature is required. However this is not just an addition

of a softer component, but is more a redistribution of the dominant temperatures. The range spanned by the three temperatures, from 5 to 15 million degrees, is not very large.

Accepted by A&A

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Solar Abstracts

Observations of the Quiet Sun's Magnetic Field

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The profiles of Stokes I and V of FeI 5247 Å, CrI 5247 Å, FeI 5250.2 Å and FeI i 5250.6 Å have been measured in the quiet photosphere with ZIMPOL, a new polarimeter, with very low noise level. The spatial resolution element of about 1 Mm was essentially determined by seeing. In about 15% of the observed area, the signal-to-noise ratio was sufficiently large to determine the strength of the magnetic field and to derive various properties of the Stokes V profiles (asymmetries, zero-crossing shift and thermal line ratio). Our results show that, at least in this fraction of area, the magnetic field in the quiet Sun is dominated by strong flux concentrations which must be rather small. The data on the Stokes V properties provide observational constraints for theoretical models of flux concentrations.

Accepted by A&A

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The Giant 1991 June 1 Flare: Evidence for Gamma Ray Production in the Corona and Accelerated Heavy Ion Abundance Enhancements from Gamma Ray Spectroscopy

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We investigated the implications of the gamma ray line emission observed with GRANAT/PHEBUS from the behind the limb flare on June 1, 1991. We showed that thin target interactions are required to account for the very high observed ratio of the nuclear line emission in the 1.1-1.8 MeV and 4.1-7.6 MeV energy bands which are populated predominantly by gamma rays from deexcitations of Ne-Fe and C-O, respectively. We found that the composition of the accelerated particles clearly shows the heavy element abundance enhancements characteristic of acceleration via resonant wave-particle interactions. Furthermore, the heavy element abundance enhancements increase with time, reaching towards the end of the flare the highest values observed in space from impulsive SEP events.

We showed that the energy deposited in the coronal interaction region is comparable to the largest total accelerated particle energy content in previously observed gamma ray flares. However, this deposited energy is small in comparison with the energy content in >20 keV electrons inferred from hard X-ray observations with Ulysses for which the 1991 June 1 flare was in full view. Approximate energy equipartition between accelerated electrons and ions then implies that the total ion energy content is much larger than the portion deposited in the corona, requiring a short ion residence time τ and low ambient density $n_{\rm H}$ in the coronal interaction region ($n_{\rm H}\tau \simeq 2.5 \times 10^9$ cm^{-3} s).

Accepted by ApJ

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Evolution of the Solar Ionizing Flux

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A young magnetically active Sun, with enhanced ionizing radiations and an elevated solar wind, might have contributed to erosion of the primordial atmosphere of Mars (which is particularly vulnerable to dissociative recombination and sputtering by solar wind pickup ions). Spacecraft and groundbased observations of solar-type dwarfs in young galactic clusters have yielded a unified view of the early evolution and subsequent systematic decline of magnetic activity with age. Rotational braking by the coronal wind ultimately quenches the spin-catalyzed "dynamo" at the heart of stellar magnetism. Decay of the 10^6–10^7 K *corona* is much faster than the 10^4 K *chromosphere*, but the XUV emissions of both can be predicted reliably, and photoionization of key planetary atmospheric constituents can be modeled. The early Martian atmosphere (age ~ 1 Gyr) probably was subjected to photoionization rates $\sim 5\times$ contemporary peak values (sunspot maximum), possibly more if the ages of galactic clusters have been systematically underestimated.

Accepted by JGR Planets

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Angular Momentum Transport by Internal Waves in the Solar Interior

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The internal gravity waves of low frequency which are emitted at the base of the solar convection zone are able to extract angular momentum from the radiative interior. We evaluate this transport with some simplifying assumptions: we ignore the Coriolis force, approximate the spectrum of turbulent convection by the Kolmogorov law, and couple this turbulence to the internal waves through their pressure fluctuations, following Press (1981) and García López & Spruit (1991). The local frequency of an internal wave varies with depth in a differentially rotating star, and it can vanish at some location, thus leading to enhanced damping (Goldreich & Nicholson 1989). It is this dissipation mechanism only that we take into account in the exchange of momentum between waves and stellar rotation. The flux of angular momentum is then an implicit function of depth, involving the local rotation rate and an integral representing the cumulative effect of radiative dissipation. We find that the efficiency of this transport process is rather high: it operates on a timescale of 10^7 years, and is probably responsible for the flat rotation profile which has been detected through helioseismology.

Accepted by A&A

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Announcement

ESA RESEARCH FELLOWSHIPS in SOLAR/HELIOSPHERIC PHYSICS

The Space Science Department (SSD) of ESA provides scientific support to ESA space science projects and undertakes research programmes covering instrument development and data analysis using space-borne and ground based facilities. The research activities in SSD are undertaken by scientific staff and ESA research fellows, with appropriate engineering and technical support. Research fellows are usually under contract for two years. In principle, fellowships will be awarded ONLY to NATIONALS from ESA member states.

Send applications and CVs by 15 November 1996 to Solar System Division (K.-P. Wenzel), Estec, Postbus 299, 2200 AG Noordwijk, The Netherlands. For further information contact the person listed or the Head of Division, telephone/fax +31-71-5653573/4697, Internet: kwenzel@estec.esa.nl

Application for up to TWO FELLOWSHIPS are solicited NOW (APPLICATIONS DUE 15 NOVEMBER 1996) for appointment in early 1997 in the following areas:

HELIOSPHERIC PHYSICS Scientists to work on Energetic Particle characteristics of Co-rotating Interaction Regions, Coronal Mass Ejections, Anomalous Cosmic Rays, shock acceleration, upstream particles or related topics. Data are available from the Ulysses, WIND and SOHO missions. Preference will be given to candidates with a strong background and interest in heliospheric physics and having experience in the interpretation of energetic particle data. Contact: Trevor Sanderson, tsanders@estec.esa.nl

SOLAR PHYSICS Scientists to work in one or several of the following research areas: Helioseismology and physics of solar variations; Solar corona and magnetic activity; Solar/stellar connection (activity, variability, circumstellar environments); Development and exploitation of related instrumentation (SOHO/LOI, MUSICOS spectrometer, CCD camera). For the analysis of SOHO data (helioseismology, photospheric-corona connection), this may include extended working periods at the SOHO Experiment Analysis Facility at NASA Goddard Space Flight Center. Contact: Bernard H. Foing, bfoing@estec.esa.nl

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` .