COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

No. 19 — May 1997 Editor: Steve Skinner (coolnews@jila.colorado.edu)

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IUE Observations of Beryllium II Lines in Lithium-Rich Giant Stars

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IUE spectra of the Beryllium II region are presented for two Lithium-rich giant stars, HD 9746 and HD 112127. In either spectrum there is no sign of significant Beryllium features at the Be II lines 3130.416 Å or 3131.064 Å, which seems to indicate that Be was depleted in these two Lithium-rich giants. This suggests that some additional Lithium was produced in their stellar interiors during the evolution along the giant branch.

Accepted by A&A Letters

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Chemical Composition of Halo and Disk Stars with Overlapping Metallicities

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High resolution ($R = 60\,000$), high S/N spectra have been obtained for 13 halo stars and 16 disk stars with $5400 < T_{\rm eff} < 6500$ K, $4.0 < \log g < 4.6$ and overlapping metallicities in the range $-1.3 <$ [Fe/H] < -0.5. Equivalent widths of weak Fe I and Fe II lines are used to determine differential values of $T_{\rm eff}$ and $\log g$. Relative abundances of O, Na, Mg, Si, Ca, Ti, Cr, Fe, Ni, Y and Ba are determined to a precision ranging from 0.02 to 0.07 dex. Kinematical data have been collected and used to calculate the stellar orbital parameters, $R_{\rm max}$, the maximum distance from the Galactic center, and $z_{\rm max}$, the maximum distance from the Galactic plane.

A group of 8 halo stars have significantly lower [α/Fe] values than disk stars of the same metallicity ($\alpha \equiv$ O, Mg, Si, Ca or Ti). These stars are also underabundant in Na and Ni and maybe in Cr. [Na/Fe] ranges from -0.4 to $+0.1$, and [Ni/Fe] is surprisingly well correlated with [Na/Fe]. The smallest values of [α/Fe] and [Na/Fe] are found for the stars with the largest values of $R_{\max}$ and $z_{\max}$. This may indicate that the anomalous halo stars have been accreted from dwarf galaxies with a chemical evolution history different from that of the inner halo and the disk. In any case the data show that abundance ratios in stars are not universal functions of [Fe/H] and that the chemical evolution of the Galaxy at [Fe/H] $\simeq -1.0$ is more complicated than assumed in many models.

One halo star, HD 106038, is found to be strongly overabundant in Si, Ni, Y and Ba relative to Fe.

Accepted by A&A

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The Solar Neighborhood IV: Discovery of the Twentieth Nearest Star System

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As part of a RECONS (Research Consortium on Nearby Stars) effort to discover stars nearer than 10 pc, LHS 1565 (GJ 1061; V = 13.03; M5.5 V) has been found to be only 3.7 pc from the Sun using a combination of photometric, spectroscopic and trigonometric parallax work. It ranks as the twentieth closest stellar system and underscores the incompleteness of the nearby star sample, particularly for objects near the end of the main sequence. Ironically, this unassuming red dwarf provides a shocking reminder of how much we have yet to learn about even our nearest stellar neighbors.

Accepted by AJ

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Differential Rotation and Magnetic Polarity Patterns on AB Doradus

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In this paper, we present the first magnetic images of the rapidly rotating young K0 dwarf AB Doradus. Simultaneous brightness images are also reconstructed. These images are obtained from two independent data sets recorded four to six nights (eight to twelve rotation cycles) apart, with the UCL Echelle Spectrograph of the Anglo-Australian Telescope in 1995 December. All images are recovered from sets of "average profiles" obtained through a least-squares deconvolution process of about 1,500 lines throughout the whole visible spectrum.

We find that about 20% of the surface of AB Dor is covered with a significant (> 200 G) field, whose flux within these magnetic regions is typically 500 G, with peaks up to 1.5 kG. The associated magnetic field topology is essentially radial (in 1995 December) and features an alternating east-west polarity structure at intermediate to high latitudes, comprising up to twelve regions of opposite polarities. We suspect that this pattern represents the emergence of buoyant flux tubes from an underlying toroidal field structure. The toroidal field itself is also detected at the photospheric level and switches from positive polarity at intermediate latitudes to negative polarity in circumpolar regions. Altogether, it suggests that the associated dynamo is probably not purely solar-like (i.e. confined to an overshoot layer at the base of the convective zone), but must also feature a significant component distributed throughout the whole convective envelope.

From the evolution of brightness maps throughout eight rotations, we infer that the pole of AB Dor rotates *slower* than the equator, by about one part in 220. The corresponding 'lap time' required for the equatorial region to lap the pole is thus of the order of 110 d, very close to the solar value of 120 d. Along with the information that the photometric period has been in steady decrease since 1988, our result implies that cool features have moved equatorward *on average* on AB Dor.

Repeated observations of the Hα-absorbing circumstellar prominence system indicate rotation periods for individual prominences that are significantly longer than those obtained for the mid-latitude magnetic features. We infer that if the prominences co-rotate with the footpoints of the magnetic structures in which they form, they must be anchored at latitudes greater than 60°.

Accepted by MNRAS

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Lithium in M67: Evidence for Spread in a Solar Age Cluster

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We present high resolution observations of main sequence stars in the solar age, solar metallicity open cluster M67. For the first time we show conclusively that a spread in lithium abundances exists among solar-type stars belonging to this cluster. This implies that standard models with only convection as a mixing mechanism can hardly account for the spread at each colour, and that the Li abundance is not a good age indicator for solar-type stars. The comparison of Li abundances in M67 (age $\sim 4.7 \times 10^9$ yrs) with those in the younger Hyades cluster ($\sim 7 \times 10^8$ yrs) shows that the less depleted stars in M67 have a Li content only ~ 0.25 dex below similar stars in the Hyades. Considering the ~ 4 Gyrs difference between the two clusters, this indicates that standard lithium destruction mechanisms are very inefficient (if present at all) in many solar-type stars during most of their main sequence lifetime. On the other hand, almost 40% of our sample stars show a significant Li depletion, with values comparable to the Sun. Our sample also includes one SB2 binary, for which a very high Li abundance was previously reported. We found an abundance significantly higher than in single stars, but our spectra are inconsistent with those previously published.

Accepted by A&A

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Chromospheric Line Blanketing and the Hydrogen Spectrum in M Dwarfs

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We present non-LTE calculations of the H I spectrum in a grid of chromospheric models that represents a dM0 star in which the activity level ranges from quiescent to very active. We investigate three different treatments of the background opacity: 1) continuous opacity only, 2) blanketing due to lines that form in the photosphere below $T_{\rm min}$, and 3) blanketing by lines that form throughout the entire outer atmosphere. We show that the predicted W_λ of Lyα in all models is reduced by as much as a factor of ≈ 4, and that of Hα in very active (dMe) stars is enhanced by a factor of about two by the inclusion of background line opacity. A consistent treatment of line blanketing that includes the effect of the chromospheric and transition region temperature structure in the calculation of background line opacity is necessary for the accurate calculation of Lyα, and in some cases Hα, in these stars. The Hα line in less active models, and the Paβ line in all models, is negligibly affected by the treatment of background opacity. We also show that, in addition to the expected suppression of emergent flux in the visible by line blanketing, the broad-band continuum flux in regions where $\lambda < 2000A$ is *increased* by as much as a factor of three in some models by the inclusion of line blanketing. This reduces the equivalent width of the Lyman series by a factor of four and is due to the veil of background lines going into emission in the UV, and to the stronger coupling of the background source function to the Planck function in the presence of blanketing by thermal lines. We confirm the results of earlier calculations that suggest the dominance of the *continuum* emission in the radiative cooling of the chromosphere. Therefore, any proposed heating mechanisms must supply at least an order of magnitude more non-radiative heating than would be required on the basis of an analysis in which only emission line cooling is considered. We also include a preliminary assessment of non-LTE effects in the background opacity on the emergent UV continua.

Accepted by A&A

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The X-ray Coronal Emission of λ Andromedae Observed with ASCA and ROSAT

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We present an observation of the long-period RS CVn binary λ And obtained with ASCA. We also discuss a previous observation by ROSAT of the same star, that we have retrieved from the public archive. There was little variation in the quiescent X-ray flux of λ And between these two observations almost 5 years apart, but they offer different, and in part complementary, views of its corona. The ASCA spectra of λ And are well described by a 2-T model with a main component at $T_1 \simeq 0.9$ keV and a smaller component at $T_2 \simeq 3$ keV, with $EM_2/EM_1 \simeq 0.15$. The fitted coronal metallicity is $Z \simeq 0.1$, much lower than solar but consistent within a factor of 2 with the reported photospheric metallicity $Z_{\rm phot} \simeq 0.2$. On the contrary, a successful 2-T fit of the ROSAT spectrum yields a cool component at $\simeq 0.5$ keV and a hotter component at $\simeq 1.4$ keV, with $EM_2/EM_1 \simeq 2$ and $Z \simeq 0.25$. Because of these differences, we were unable to find an acceptable fit to the joint ASCA and ROSAT data. We discuss possible causes for the discrepancy, including spectral time variability, uncertainties in the plasma emission codes and in the instrumental calibration, and limitations in the adopted fitting model. The hydrogen column density toward λ And, well constrained by ROSAT, is $N_{\rm H} \simeq 1 \times 10^{19}$ cm^{-2}, a factor ~ 2 larger than estimated from UV observations from Copernicus and the Hubble Space Telescope. Albeit small, this difference may indicate the presence of substantial ionization of the interstellar medium.

Accepted by A&A

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Structure and Evolution of Low-mass Stars

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We present extensive calculations of the structure and the evolution of low-mass stars in the range 0.07-0.8 $M_\odot$, for metallicities $-2.0 \le [M/H] \le 0.0$. These calculations are based on the most recent description of the microphysics characteristic of these dense and cool objects and on the lattest generation of grainless non-grey atmosphere models. We examine the evolution of the different mechanical and thermal properties of these objects as a function of mass and metallicity. We also demonstrate the inaccuracy of grey models and $T(\tau)$ relationships under these conditions. We provide detailed tables of the mass-radius-luminosity-effective temperature relations for various ages and metallicities, aimed at calibrating existing or future observations of low-mass stars and massive brown dwarfs. We derive new hydrogen-burning minimum masses, within the afore-mentioned metallicity range. These minimum masses are found to be smaller than previous estimates, a direct consequence of non-grey effects.

At last, we examine the evolution of the abundance of light elements, Li, Be and B, as a function of age, mass and metallicity.

Accepted by A&A

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Evolutionary Models for Metal-poor Low-mass Stars. Lower Main Sequence of Globular Clusters and Halo Field Stars

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We have performed evolutionary calculations of very-low-mass stars from 0.08 to 0.8 $M_\odot$ for different metallicites from [M/H]= -2.0 to -1.0 and we have tabulated the mechanical, thermal and photometric characteristics of these models. The calculations include the most recent interior physics and improved non-grey atmosphere models. The models reproduce the entire main sequences of the globular clusters observed with the Hubble Space Telescope over the aforementioned range of metallicity. Comparisons are made in the WFPC2 *Flight* system including the F555, F606 and F814 filters, and in the standard Johnson-Cousins system. We examine the effects of different physical parameters, mixing-length, α-enriched elements, helium fraction, as well as the accuracy of the photometric transformations of the HST data into standard systems. We derive mass-effective temperature and mass-magnitude relationships and we compare the results with the ones obtained with different grey-like approximations. These latter are shown to yield inaccurate relations, in particular near the hydrogen-burning limit. We derive new hydrogen-burning minimum masses, and the corresponding absolute magnitudes, for the different metallicities.

We predict color-magnitude diagrams in the infrared NICMOS filters, to be used for the next generation of the HST observations, providing mass-magnitudes relationships in these colors down to the brown-dwarf limit. We show that the expected signature of the stellar to substellar transition in color-magnitude diagrams is a severe blueshift in the infrared colors, due to the increasing collision-induced absorption of molecular hydrogen with increasing density and decreasing temperature.

At last, we apply these calculations to the observed halo field stars, which yields a precise determination of their metallicity, and thus of their galactic origin. We find no evidence for significant differences between the halo field stars and the globular cluster sequences.

Accepted by A&A

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Simultaneous ORFEUS FUV and ROSAT X-ray Observations of the Young Rapid Rotator AB Doradus

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We present simultaneous soft X-ray and FUV observations of the rapidly rotating young star AB Doradus (HD 36705), obtained with the position sensitive proportional counter (PSPC) on board ROSAT and the FUV/EUV spectrometer on board ORFEUS. The X-ray data show that AB Dor was in a high state, possibly in a flare, during the FUV observations. The lines of CIII at 977 Å and OVI at 1032 and 1038 Å are clearly detected in the ORFEUS spectrum. The overall emission measure distribution of the combined FUV and X-ray data is steeply rising. The OVI 1032 Å line is definitely broadened with respect to the instrumental line profile, however, the observed broadening does not exceed the photospheric $vsin(i)$-value. This strongly suggests that the observed OVI emission, formed at a characteristic temperature of $\approx$ 300000 K, is produced almost exclusively relatively close to the star's surface, and not in an extended corotating emission region with scale sizes of a few stellar radii.

Accepted by A&A

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First HST Observations of Mira AB Wind Accreting Binary System

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The Mira AB system belongs to a class of detached binaries in which a compact object accretes mass from the wind of a cool giant or supergiant. This system provides a unique laboratory for detailed study of the characteristics of the wind accretion processes because it can be spatially resolved with the HST and the components can be studied individually at UV and optical wavelengths.

We resolved the components of this binary using the HST Faint Object Camera (FOC) images and obtained spectra of each component separated for the first time. The multiwavelength FOC images combined with the spectra provide a unique perspective of this accreting system and its components at wavelengths ranging from 150 nm to 550 nm. We determined the spectral energy distribution of each component unambiguously at UV and optical wavelengths and obtained the first high spatial resolution images of Mira A and Mira B at UV wavelengths. We detected significant asymmetries in the giant's atmosphere and found evidence for possible interaction with its companion.

Accepted by ApJ Letters

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Doppler Imagery of The Spotted RS CVn Star HR 1099 (= V711 Tau) from 1981 - 1992

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We present 23 Doppler images of the spotted RS CVn star HR 1099 from 1981 to 1992. HR 1099 shows a large cool polar spot which has persisted for the 11 years of this study and other low-latitude spots which come and go on relatively short timescales. The polar spot has variable protuberances which look very similar to the time-variable vertical extensions of the Sun's polar coronal hole. The area of the polar spot and its extensions shows marginal evidence of being periodically variable in time with a period of 3 years. On several occasions, isolated prominent spots emerged and then disappeared near the equator. The tracks of two long-lived spots suggest that some spots which emerged at low or intermediate latitudes migrated up to the pole in a clockwise spiral (slower than the orbit), and then apparently merged with the polar spot. Differential rotation as measured from spot movements showed that intermediate and low latitudes rotate slightly slower than the orbital angular velocity, while the pole and highest latitudes appear to be synchronized to the orbit. The differential rotation is of opposite sign and a factor of 50 less than for the Sun. We propose that the starspots on HR 1099 and other rapidly rotating RS CVn stars are, by analogy with solar coronal holes, large unipolar magnetic regions tightly frozen into multi-kilogauss axisymmetric dipole fields in these stars. Since the large cool polar spots, the signature of these dipoles, are not present on more slowly rotating RS CVn stars, we believe that they must be dynamo-induced rather than remnant fossil fields.

Submitted to ApJ Supp.

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Hipparcos Distances of X-ray Selected Stars: Implications on Their Nature as Stellar Population

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We present the parallaxes, measured by Hipparcos, for a sample of X-ray selected stars. The stars belong to the stellar sample of the *Einstein Extended Medium Sensitivity Survey*. They are all at galactic latitude $|b| > 20\,\mathrm{deg}$, and are generally far away from known star forming regions. Several of these stars show lithium abundance and activity level typical of very young stars with ages comparable to that of the Pleiades. We show that the majority of our sample stars are on the main sequence, with only $\approx 20\%$ being giants. We do not find a significant presence of pre-main sequence stars in our sample, notwithstanding the fact that some of our stars have a considerable lithium abundance, showing that the stars observed are most likely young and active main-sequence objects.

Accepted by A&A

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A Planet Orbiting the Star Rho Coronae Borealis

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We report the discovery of near-sinusoidal radial velocity variations of the G0V star ρ CrB, with period 39.6 days and amplitude 67 m s^{-1}. These variations are consistent with the existence of an orbital companion in a circular orbit. Adopting a mass of 1.0 $M_\odot$ for the primary, the companion has minimum mass about 1.1 Jupiter masses, and orbital radius about 0.23 AU. Such an orbital radius is too large for tidal circularization of an initially eccentric orbit during the lifetime of the star, and hence we suggest that the low eccentricity is primordial, as would be expected for a planet formed in a dissipative circumstellar disk.

Accepted by ApJ Letters

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Common Envelope Evolution and Lithium in V471 Tau

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We have observed the spectral regions around the LiI resonance and subordinate 610.4 nm lines of V471 Tau. This is an eclipsing post common-envelope (CE) binary system. A revision of several independent measurements of the parallax and proper motion of V471 Tau allow us to argue that this system is indeed a Hyades cluster member by examining and rejecting earlier, flawed results. Using spectral synthesis and taking into account NLTE effects, we have derived a photospheric Li abundance of log N(Li)=2.35 for the K dwarf, which is a factor 100 higher than single Hyades members of the same mass. We argue that two mechanisms are responsible for this: a) Accretion of a substantial amount of Li-rich material onto the K dwarf during CE evolution inside the giant precursor of the white dwarf. Recently, a number of Li-rich giants have been observed and they appear to undergo large mass-loss. We speculate that CE evolution could actually explain the properties of these giants as well. b) Reduced Li depletion in the K dwarf due to sustained fast rotation in a short-period tidally-locked orbit. This process accounts for the preservation of Li after CE evolution has ceased.

Accepted by A&A

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The EUV spectrum of Kappa Cet: an Active Sun

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The Spectrum of K Cet in the region 80 - 370 Å observed by EUVE spectrometers is analyzed to investigate the transition region and the corona of the star. The star appears to be in a rather quiet condition and no evidence exists of flare-like lines observed in many active stars. Several emission lines of moderately ionized iron (from Fe IX to Fe XVIII) are identified and used together with I.U.E. observations to evaluate the Differential Emission Measure (d.e.m.). The d.e.m. peaks at about $3{\cdot}10^6$ K, a value typical of solar active regions. This is confirmed by a comparison

with the spectrum of an active region of the solar corona measured by the Coronal Diagnostic Spectrometer on SOHO showing very similar features.

Accepted by A&A

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Optical High-Resolution Spectroscopy of ROSAT Detected Late-type Stars South of the Taurus Molecular Clouds

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We study 111 late-type stars found with optical follow-up observations of ROSAT All-Sky Survey sources south of the Taurus molecular clouds. Some 30 of them have been claimed to be weak-line T Tauri stars, low-mass pre-main sequence (PMS) stars, based mainly on the presence of strong lithium 6708Å absorption in intermediate-resolution ($\sim$ 1Å) spectra. We obtained single-order echelle spectra at blue wavelengths for 106 of these stars, in order to measure their radial and rotational velocities, and investigate their angular momentum evolution and kinematic membership to the Taurus clouds. In addition, we obtained echelle spectra with high ($\sim$ 0.25Å) resolution for seven stars to measure precisely the lithium equivalent width W_λ(Li). We find that $\sim$ 1Å resolution is sufficient in order not to overestimate W_λ(Li), e.g. due to blending. Of our 111 stars, 19 are located on the λ Ori cloud, nine of which are K-type stars with lithium in excess of the zero-age-main-sequence (ZAMS) level, i.e. are PMS stars. At least 40 of the remaining 92 off-cloud stars display detectable lithium, 24 of which are lithium-excess stars, i.e. show lithium at least as strong as IC 2602 stars with the same spectral types. Of those 24 stars, nine (25% of the off-cloud stars with detectable lithium) are PMS stars isolated from cloud material; all have spectral type K, and three of them are spectroscopic binaries. 15 off-cloud stars have spectral type G and lithium comparable to IC 2602 stars, i.e. may have already arrived on the ZAMS just like G-type IC 2602 stars. However, all these 24 off-cloud lithium-excess stars are probably not older than IC 2602 ($\sim 3 \cdot 10^7$ yrs). We discuss possible sites and modes of origin of the isolated PMS stars south of Taurus.

Accepted by A&A

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Editor's Note: The above cross-disciplinary abstract has also appeared in the *Star Formation Newsletter*.

Soft X-ray Emission from Intermediate-age Open Clusters: NGC 6940

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We present the results of soft X-ray observations of the intermediate-age open cluster NGC 6940 performed with the ROSAT PSPC. We detected 18 sources, four of which are identified with member stars of the cluster and five with active field stars. Another source is identified with an active giant star that could belong to the cluster, although it is not classified as a cluster member. The remaining eight, most likely of extragalactic nature, need to be identified through optical follow-up. As in the case of old clusters such as M 67 and NGC 752, a high fraction of the detected members are binaries: in NGC 6940 three out of four of the identified members are among the only six binaries known in the cluster. All four sources have X-ray luminosities typical of RS CVn binaries. However, only two of the three detected binaries have system characteristics typical of active X-ray binaries. The high X-ray luminosity of the other two sources needs to be explained. All four identified members are red giants, in agreement with the presence of a saturation level. The four field stars identified as counterparts of X-ray sources are all very active, with X-ray luminosities in the range $10^{29} - 10^{30}$ erg s^{-1}, and deserve further optical investigation. We confirm the results found in other old open clusters, i.e. that binaries are still very active coronal sources at an age larger than 1 Gyr, and that good spatial resolution images in the X-ray band are a powerful tool to investigate their evolution in clusters of different ages.

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Solar Abstracts

Deep Survey of Solar Nano-Flares with Yohkoh

Toshifumi Shimizu[1] and Saku Tsuneta[1]

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Short time-scale variability fainter than transient brightenings (microflares) is found in the solar position-dependent light curves observed with the Yohkoh Soft X-Ray Telescope. The time variability is found almost everywhere in active regions and X-ray bright points, while no significant variability is found in quiet regions. An intensity correlation is found between the magnitudes of the time variability and the intensities of the persistent corona. The time variability is apparently related to the heating mechanism of the persistent active-region corona. The intensity correlation can be explained with the idea that the persistent corona is made of extremely numerous nanoflares, larger ones of which are observed as the time variability. The alternative explanation is that a common parameter controls both the persistent corona and the time variability.

Accepted by ApJ

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Acoustic Wave Propagation in the Solar Atmosphere. V. Observations Versus Simulations

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We study the evolution of spectra of acoustic waves that are generated in the convection zone and propagate upward into the photosphere, where we compare the simulated acoustic spectra with the spectrum observed in an Fe I line. Although there is no pronounced 3 min component in the spectra generated in the convection zone, there are dominant 3 min features in the theoretical spectra, in agreement with the observed spectrum. We interpret the occurrence of the 3 min features as the response of the solar atmosphere to the acoustic waves which shifts high frequency wave energy to low frequencies. We also find qualitative agreement for the acoustic power between the wave simulations and the observations.

Accepted by A&A

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On a Babcock-Leighton Solar Dynamo Model with a Deep Seated Generating Layer for the Toroidal Field. IV

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The study is continued of a dynamo model of the Babcock-Leighton type (i.e., the surface eruptions of toroidal magnetic field are the source for the poloidal field) with a thin, deep seated layer (GL), for the generation of the toroidal field, B_ϕ. The partial differential equations satisfied by B_ϕ and by the vector potential for the poloidal field are integrated in time with the help of a second order time- and space-centered finite different scheme. Axial symmetry is assumed; the gradient of the angular velocity in the GL is such that within this layer a transition to uniform rotation takes place; the meridional motion, transporting the poloidal field to the GL, is poleward and about $3\mathrm{ms}^{-1}$ at the surface; the radial diffusivity, η_r, equals $5 \times 10^9\mathrm{cm}^2\mathrm{sec}^{-1}$, and the horizontal diffusivity, η_θ, is adjusted to achieve marginal stability. The initial conditions are: a negligible poloidal field, and a maximum value of $|B_\phi|$ in the GL equal to

$1.5 \times B_{cr}$, where B_{cr} is a prescribed field.
For every time step the maximum value of $|B_\phi|$ in the GL is computed. If this value exceeds B_{cr}, then there is eruption of a flux tube (at the latitude corresponding to this maximum) that rises radially to the surface. Only one eruption is allowed per time step (Δt) and B_ϕ in the GL is unchanged as a consequence of the eruption. The ensemble of eruptions is the source for the poloidal field, i.e. no use is made of a mean field equation relating the poloidal- with the toroidal-field. For a given value of Δt, and since the problem is linear, the solutions scale with B_{cr}. Therefore the equations need to be solved for one value of B_{cr} only.
Since only one eruption is allowed per time step, the dependence of the solutions on Δt needs to be studied. Let F_t be an arbitrary numerical factor (=3 for example) and compare the solutions of the equations for $(B_{cr}, \Delta t)$ and $(B_{cr}, \Delta t/3)$. It is clear that there will be three times as many eruptions in the second case (with the shorter time step) than in the first case. However, if the erupted flux in case one is multiplied by three, then the solutions for this case become nearly identical to those of case two (Δt is shorter than any typical time of the system, and the difference due to the unequal time steps is negligible). Therefore varying the time step is equivalent to keeping Δt fixed while multiplying the erupted flux by a factor, F_t. In the numerical calculations Δt was set equal to 10^5s. The factor F_t can then be interpreted as the number of eruptions per 10^5s. The integration of the equations shows that there is a transition in the nature of the solutions for $F_t \approx 2.5$. For $F_t < 2.5$, the eruptions occur only at high latitudes whereas for $F_t > 2.5$, the eruptions occur for $\theta >\approx \pi/4$, where θ is the polar angle. Furthermore, for $F_t < 2.5$, the toroidal field, $|B_\phi|$, in the GL can become considerably larger than B_{cr} while this ceases to be the case for $F_t > 2.5$.
The factor F_t is an arbitrary parameter in the model and an appeal to observations is necessary. We set $B_{cr} = 10^3$G. In the model, the magnetic flux of erupting magnetic tubes, is then about 3×10^{21}G, of the order of the solar values. For this value of B_{cr} and for the value of $F_t(\approx 2.5)$ at which the transition takes place, the total erupted flux in 10 years is about 0.85×10^{25}Mx in remarkable agreement with the total erupted flux during a solar cycle. Concerning the dynamo models studied here, a major drawback encountered in previous papers has been the eruptions at high latitudes, that entail unrealistically large values for the the radial magnetic field at the poles. The results of this paper provide a major step forward in the resolution of this difficulty.

Accepted by ApJ

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Prominence Oscillations and Stability; Communicating the Distant Photospheric Boundary

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The photosphere provides an important boundary condition for prominence support. The conservation of photospheric flux (sometimes called line tying) sets a serious constraint on the evolution of coronal magnetic fields. This boundary condition can only be communicated to the prominence by Alfvén and magneto-acoustic waves. As a result, the boundary condition as experienced by the prominence at height h lags behind a time $h/v_{\rm A}$ ($v_{\rm A}$: Alfvénspeed) as compared to the instantaneous situation at the location of the photosphere.

In this paper I study vertical oscillations and stability of prominences, taking retardation effects into account. An equation of motion for a Kuperus-Raadu prominence is derived, describing the prominence as a line current and the photosphere as a perfectly conducting plate. Solving this equation of motion implies solving the full time-dependent Maxwell equations, thus guaranteeing a realistic field evolution under the constraint of photospheric flux conservation.

The results indicate that the travel time $h/v_{\rm A}$ is an important parameter of the system as it influences the decay or growth times of prominence oscillations greatly. A new kind of instability is found, whereby the prominence experiences oscillations growing in time, even in the nonlinear regime. This instability occurs when the travel time $h/v_{\rm A}$ is comparable to or greater than the oscillation period. Also, forced oscillations can only be significant for rather precisely matched values of $h/v_{\rm A}$ and the driving period.

Accepted by A&A

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Vertical Prominence Oscillations and Stability; A Comparison of the Influence of the

Distant Photosphere in Inverse Polarity and Normal Polarity Prominence Models

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All MHD models for prominence equilibrium to date can, in essence, be reduced to two simple current models that describe so-called Inverse (IP) and Normal (NP) Polarity topologies. Using these simple current models, I investigate the influence of the boundary condition provided by the distant photosphere (flux conservation) on vertical prominence oscillations.

The fact that the photosphere is some distance z away from the prominence, implies that the Lorentz force acting on the prominence, due to the photospheric boundary condition, evolves with a delay z/v_{A} (v_{A}: coronal Alfvénspeed).

In an earlier paper (Schutgens 1997), it was shown that, in the case of a Kuperus-Raadu (IP) prominence, this delay can greatly influence the vertical stability properties of prominences, especially when $\omega\tau_0 \approx 1$ or larger (ω: frequency of oscillation, $\tau_0 = 2z/v_{\mathrm{A}}$).

In this paper a comparative study is made of this effect in IP and NP prominences.

Because of a different force balance, NP and IP prominences have currents and oscillation periods of different magnitude. The influence of the distant photosphere on NP prominences is minimal, while it has a very pronounced effect on IP prominences. As a result, NP and IP prominences have widely different stability properties. Foot point shaking due to photospheric 5 min. oscillations will only excite IP prominences.

Accepted by A&A

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Sustaining the Quiet Photospheric Network: The Balance of Flux Emergence, Fragmentation, Merging, and Cancellation

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The magnetic field in the solar photosphere evolves as flux concentrations fragment in response to sheared flows, merge when they collide with others of equal polarity, or (partially) cancel against concentrations of opposite polarity. Newly emerging flux replaces the canceled flux. We present a quantitative statistical model that is consistent with the histogram of fluxes contained in concentrations of magnetic flux in the quiet network for fluxes exceeding $\approx 2 \cdot 10^{18}$ Mx, as well as with estimated collision frequencies and fragmentation rates. This model holds for any region with weak gradients in the magnetic flux density at scales of more than a few supergranules. We discuss the role of this dynamic flux balance (i) in the dispersal of flux in the photosphere, (ii) in sustaining the network–like pattern and mixed–polarity character of the network, (iii) in the formation of unipolar areas covering the polar caps, and (iv) on the potential formation of large numbers of very small concentrations by incomplete cancellation. Based on the model, we estimate that as much flux is cancelled as is present in quiet–network elements with fluxes exceeding $\approx 2 \cdot 10^{18}$ Mx in 1.5 to 3 days, which is compatible with earlier observational estimates. This time scale is close to the time scale for flux replacement by emergence in ephemeral regions, so that this appears to be the most important source of flux for the quiet–Sun network; based on the model, we cannot put significant constraints on the amount of flux that is injected on scales that are substantially smaller than that of the ephemeral regions. We establish that ephemeral regions originate in the convection zone and are not merely the result of the re–emergence of previously cancelled network flux. We also point out that the quiet, mixed–polarity network is generated locally, and that only any relatively small polarity excess is the result of flux dispersal from active regions.

Accepted by ApJ

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Ph.D. Thesis Abstract

Small Solar Flares in Radio and X-rays: Microflares and Radio Bursts

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Ph.D degree awarded: February 1997

The hot temperature of the solar corona is still not understood. To compensate radiative and conductive losses, the corona has to be heated by some energy release mechanisms. Signatures of such energy releases are flares. The flares presented in this thesis are observed in radio waves and X-ray and are many orders of magnitude smaller than the large flares observed in active regions. The aim of these investigations is to corroborate the fragmented nature of the energy release in flares, to discuss possible emission mechanisms, to reconstruct the geometry of the investigated events, to check existing theories and propose new ones, and to approximate the contribution of these events to coronal heating. The small flares presented in this thesis are detected in decimetric and metric radio waves and in soft X-rays. Observations in these two different ranges in wavelength give different informations: The radio emissions are mostly produced by non-thermal particles by a coherent emission mechanism, whereas the soft X-ray radiation is thermal emission (bremsstrahlung) of the hot plasma. Hence, the radio emissions yield information on the non-thermal nature of the plasma and the acceleration of energetic particles, and the soft X-ray observations show the magnetic field geometry in the corona outlined by density and temperature differences in the various magnetic structures and allow to approximate the released energy in the flares. For a clear identification of associated emissions in radio and soft X-ray, spectral radio data and imaging data at both wavelengths are indispensable. The observations are mainly taken by three instruments:

- The broadband radio spectrometer Phoenix of ETH Zürich observing form 0.1 GHz to 4 GHz.
- The Very Large Array (VLA), a radio interferometer operated by Associated University, Inc.
- The Soft X-ray Telescope (SXT) on-board the satellite Yohkoh which is constructed and supported by an international collaboration of ISAS, NASA, and SERC.

The small flares selected for this study are (i) *narrowband spikes* in the decimetric range occurring simultaneously in well separated frequency bands, (ii) *metric spikes* , (iii) *type I radio noise storms* , and (iv) *microflares* in the magnetic network of the quiet corona. The decimetric spikes are selected from survey-type observations, whereas the other events are observed during joint observations. The metric spike events and the radio noise storm data are observed during the past solar maximum: The spectral radio observations are used to classify the emission, and the VLA data show the location of the source region on the solar disk and allow to identify possible associated emissions in soft X-ray. The quiet corona observations are taken in 1995 during joint VLA-Yohkoh observations. The location of soft X-ray brightenings are compared with radio maps at centimetric wavelengths. The main results of these investigations are as following:

- The ratios of frequency bands of narrowband spikes are *not* harmonic, i.e. the ratios are non-harmonic. The observed ratios require an emission mechanism at ratio of 5:7, or 2.5:3.5, with significant variations around this value. The performed growth rate calculations of the electron cyclotron maser instability do not reproduce these value assuming coronal conditions.

- The interferometric observations of narrowband metric spikes show a fragmented source region: Simultaneous emission in three sources separated up to $130''$ ($\approx 10^5$ km) are found. The most surprising observational fact is the high altitude of the spike source above the photosphere of about $\approx 5 \cdot 10^5$ km at 333 MHz. Besides the upwards moving electrons producing the type III emission at higher altitude in the corona, there are also downwards moving particles as suggested by thermal sources observed at lower altitude. The total energy released during a metric spike event is approximately 10^{26} erg. The new observational results are used to propose a consistent new model for metric spike events.

- In type I noise storms, no obvious correlation in the flux density of the burst sources and the continuum source is found, and there is also no related activity observed at lower altitude. The location of the continuum emission is found to be in a dense loop. The density of this loop is compatible with fundamental plasma emission. An unexpected result is the positions of the burst sources relative to the continuum source. The burst sources are separated by about $100''$ ($\approx 7 \cdot 10^4$ km) from the continuum source in perpendicular direction to the magnetic field configuration. The observed geometry contradicts the predictions of existing type I theories.

- The investigated region of the quiet corona shows several soft X-ray brightenings with approximated energies of about 10^{25} erg. For all of these brightenings, radio emissions correlating in space and time are found. There are several similar behaviors between these brightenings and solar flares occurring in active regions, such as the temporal evolution, the ratio of radio to X-ray luminosity, and the variations in temperature and emission measure during these brightenings. Therefore, these brightenings are defined as microflares.

The radio events detected in the metric range, such as metric spikes, are too rare to give a significant contribution to heat the corona. The contribution of noise storms is still unclear, whereas the observed microflares in the quiet corona may be important: The extrapolated occurrence rate of microflares with energies around 10^{25} erg gives a heating rate which is about an order of magnitude smaller than needed to heat the quiet corona. Future observations with a better sensitivity may detect even smaller microflares which may be responsible for the heating in the quiet corona.

Thesis-related Publications: A&A 285, 1038; A&A 302, 551; SP 160, 151; A&A 317, 569

Ph.D. Thesis Abstract

Circumstellar Envelopes of Red Supergiant Stars

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Ph.D dissertation directed by: R. J. Cohen

Ph.D degree awarded: April 1997

Four late-type red supergiant stars, S Per, VX Sgr, VY CMa and NML Cyg, have been observed at 1.6 and 22 GHz using MERLIN in spectral line mode. In broad outline the traditional picture is seen, in which the 22 GHz water masers are found closer to the star in a thick ring. OH mainline masers (at 1665 and 1667 MHz) are patchily distributed from the middle of the water maser region outwards, and OH 1612 MHz emission is found at larger radii with a twin peaked velocity profile. Much interesting detail is revealed by the high resolution and sensitivity of MERLIN. The water masers form a shell of radius 10^{13} to 10^{14} m, over which the velocity typically doubles from 10 to 20 km s^{-1}. The stellar wind is gravitationally bound to the star at the inner edge and unbound at the outer.

The 22 GHz maser brightness temperatures are 10^5 - 10^{13} K. Maser components are found in groups of 5 - 10 separated by $\sim$ 1 mas in successive channels over a $V_{\rm LSR}$ of $\sim$ 1 km s^{-1}. In S Per, the first direct measurements of the unbeamed masing blob radius were made, 10^{12} m at $\sim 1.5 \times 10^{13}$ m from the star. This was used to derive the beaming angle which showed that the brightest masers are on the verge of saturation. The inner radius of 22 GHz emission is determined by the maser quenching density. This is 10 - 100 times higher than the density estimated from CO and dust observations, and predicts an inner limit for OH 1612 MHz masers ten times larger than the observed radius. This shows that mass loss from these stars is clumpy and the 22 GHz H_2O masering blobs are about 20 times denser than their surroundings. The outflow is driven by radiation pressure on dust and the water masers show tangential beaming indicative of greater acceleration; the OH masers are radially beamed, consistent with the origins of the latter in less dusty inter-clump regions. The method derived by Chapman & Cohen (MNRAS, 220, 513) was used to find the dust absorption coefficient which increases with radius from ≤ 0.1 - ≤ 1.0 m^2 kg^{-1}. The low values near the star are similar to those found from laboratory studies of small grains of crystalline silicates or metal oxides in hot conditions, while astronomical silicates are more efficient absorbers. This suggests that grain growth and annealing takes place out to large distances from the star.

Water maser emission from S Per is elongated E-W while the OH emission is extended N-S. In VX Sgr the 22 GHz masers show a velocity axisymmetry in line with the direction of the magnetic field axis found from Zeeman splitting of OH emission. The 22 GHz shell in VY CMa has a radius of 300 - 400 mas elongated E-W, but the OH emission is extended N-S, 1667 MHz and 1612 MHz masers occuring up to 5 arcsec from the star. In VY CMa almost all H_2O maser features observed by MERLIN in 1994 could be matched with features mapped in 1985 using the VLA (Bowers et al. AJ, 105, 284). Expansion proper motions of 8.8 - 31.2 km s^{-1} were found. In NML Cyg two features separated by 600 mas, symmetrical in position and velocity about the assumed stellar location were matched with features observed by Yates & Cohen (MNRAS, 270, 958) in 1985 and their increase in separation corresponds to an expansion velocity of 19 ± 4 km s^{-1}. OH 1612 MHz masers and dust emission are elongated along the same position angle. This could the the onset of bipolar outflow as the star evolves towards its eventual fate as a supernova.

Thesis-related Publications: MNRAS, 282, 665

Thesis available via anonymous ftp: ftp to *ftp.jb.man.ac.uk*, then *cd pub/amsr* .

Ph.D. Thesis Abstract

Spectroscopic Measurements of Starspot Parameters on Active Stars

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Ph.D dissertation directed by: James E. Neff

Ph.D degree awarded: August 1997

This thesis describes spectroscopic techniques for studying starspots on magnetically active stars. First I use the strengths of the titanium oxide bands at 7055 Å and 8860 Å to measure the temperature and filling factor of starspots. A strength of this technique is its ability to determine spot parameters in cases where other techniques have difficulty: slowly-rotating stars, uniformly-spotted stars, and stars that always have spots. In an active star spectrum, the ratio of the depths of the two absorption bands measures the temperature of the starspots, while the absolute depths are a function of the total area of spots on the visible hemisphere of a star. I apply this technique to spectra of the RS CVn systems II Pegasi, EI Eridani, σ Geminorum, and V1762 Cygni, and the FK Comae system V1794 Cygni. Starspots on giant and subgiant active stars are better modeled using comparison spectra of giants than dwarfs. Over multiple epochs of observation, the starspot filling factors on these stars range from below the detection threshold ($\approx$8%) to just under 60%. In some cases, I find that significant starspot coverage was likely present at historical light maxima, strongly implying that spots are always present on certain stars. This TiO band technique can constrain starspot parameters for spot temperatures up to 4000 K, the temperature at which the 7055 Å TiO bands become too weak to measure in the spectrum of an active star.

I also analyze echelle spectra of eight active giant and subgiant stars and a grid of comparison stars. These observations permit the simultaneous monitoring of many molecular bands and chromospheric emission features. In addition to the 7055 Å and 8860 Å bands of TiO, I use comparison star spectra to empirically model the strong band of TiO near 6158 Å and the set of bands beginning near 6650 Å. I find that fitting absorption bands other than the TiO 7055 Å and 8860 Å features does not substantially extend the temperature range or sensitivity of this technique. The 8860 Å band is critical for accurately measuring spot parameters due to its temperature sensitivity, which differs greatly from the sensitivities of the other bands studied. For II Peg in Fall, 1992, I find that the levels of emission in the Ca II infrared triplet are correlated with starspot filling factors; this is expected if the starspots are spatially coincident with the plage that produces the emission features.

Next I present the first Doppler imaging study to use TiO absorption bands as an additional temperature constraint, work done in collaboration with N. E. Piskunov. I describe how TiO-band spectroscopy can be used in conjunction with Doppler imaging to completely determine the spatial distribution of photospheric temperature on rapidly-rotating, active stars. A preliminary version of this technique is applied to II Peg; Doppler imaging constrained by TiO-band spectroscopy yields an average spot temperature $\approx$350 K cooler than that given by Doppler imaging alone.

Finally, I extend this investigation into the H-band infrared by analyzing two absorption lines of OH near 1.563μm in spectra of three active stars (II Peg, V1762 Cyg, and λ Andromedae) and a grid of comparison stars. I find that, in inactive stars, the equivalent width of this line pair increases approximately linearly as effective temperature decreases from 5000 K to 3000 K. OH dissociates at a higher temperature than does TiO, so its lines are potentially useful for studying starspots as warm as $\sim$4600 K. Also, starspots are much brighter, relative to the unspotted photosphere, in the infrared than they are in the visible, and thus make a greater contribution to the overall spectrum of the active star. Compared to inactive stars of similar spectral types, the spectra of active stars show clear excesses of OH absorption; this is the first reported detection of OH absorption from spots on stars other than the Sun.

Thesis-related Publications: ApJ, 452, 879; ApJ, 463, 766; AJ, 113, 1129

Upcoming Meetings

International Colloquium on

ASYMPTOTIC GIANT BRANCH STARS

to be held in Montpellier, France,

AUGUST 28 - SEPTEMBER 1 , 1998

Chair : C. Waelkens (christoffel@ster.kuleuven.ac.be) Co-Chair : T. Lebertre (lebertre@obspm.fr)

Purpose :

Asymptotic Giant Branch (AGB) stars occupy the evolutionary stage which is decisive for the final fate of low- and intermediate-mass stars. Once a star has left the AGB, nuclear burning soon stops and, after the short but spectacular planetary-nebula phase, the stellar remnant cools to become a white dwarf.

The study of AGB stars is important for stellar structure and evolution, for the understanding of the interstellar and circumstellar media and for the dynamical and chemical evolution of galaxies. The observational study of AGB stars has been triggered enormously by the recent advances in optical-detector technology, which enable high-resolution spectroscopic studies of faint stars, and maybe more even by the advances in infrared, submm and mm astronomy, which now enable detailed scrutiny of the circumstellar environment and can probe AGB stars in remote and obscured places.

Current work on AGB stars is relevant for stellar evolution, stellar populations, stellar pulsation, stellar mass loss, circumstellar matter, galactic evolution, but also for understanding meteorites and solar-system dust. Clearly, the subject of AGB stars has now become sufficiently mature so as to warrant a dedicated conference which will attract researchers from different disciplines all over the world.

More information about that colloquium can be found on our Web pages :

http://www.dstu.univ-montp2.fr/GRAAL/agb98-1.html

We strongly recommend you to fill in a pre-registration form available on our web site (http://www.dstu.univ-montp2.fr/GRAAL/agb98/regist.html) or upon request at agb98@graal.univ-montp2.fr (only if you can not have any access to the Web) and return it by June 15th.

Please, forward this message to any of your colleague who may be interested.

Sincerely yours,

For the Local organisation committee:

Agnes LEBRE,

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Job Announcement

Research Assistantship in Modelling of Circumstellar Environments beginning September 1997 at ARMAGH OBSERVATORY

Applications are invited for a 13 month research assistantship in the modelling of circumstellar environments, funded by the UK PPARC, with the possibility of an extension. The candidate should have obtained their PhD prior to appointment, preferably with experience in modelling of dust environments and/or stellar atmospheres.

Current research interests of staff members at Armagh Observatory include the following areas:

- **Solar physics**
- **Stellar atmospheres**
- **Solar-terrestrial physics**
- **Circumstellar environments**

The Observatory has a staff of seven astronomers, six post docs, seven research students, plus additional support staff. Extensive use is made of the local STARLINK computers (Alpha workstations), which are part of the N. Ireland STARLINK node. Applications, including a CV and the names of three referees should be forwarded before 15 June 1997 to **The Administrator, Armagh Observatory, College Hill, Armagh BT61 9DG, N. Ireland**. Any requests for further information should be addressed to the same point, or to **Dr J.G. Doyle (email — jgd@star.arm.ac.uk)**. For further details on the Observatory and our research interests one should check the WWW at: **http://star.arm.ac.uk/research.html** . Additional information on the research interests of the PI may be found on the WWW at: **http://star.arm.ac.uk/~jgd/gerry.html**.

Studentship Opportunity

Graduate Studentship beginning October 1997 in Solar Physics at ARMAGH OBSERVATORY

Applications are invited for a three year studentship at **Armagh Observatory** beginning 1 October 1997. The successful student should have at least an upper second class honours degree in either Physics, Astronomy or Applied Mathematics and would enroll for a PhD at Queen's University Belfast. They will carry out their research programme at Armagh under the joint supervision of QUB and Armagh personnel. The research project will be in the area of solar astrophysics, in particular, data relating to the SOHO mission. The student should have a good physics and/or mathematical background, and will involve both reduction & modelling of the data.

Current research interests of staff members at Armagh Observatory include the following areas:

- **Solar physics**
- **Stellar atmospheres**
- **Solar-terrestrial physics**
- **Circumstellar environments**

(*continues on next page →*)

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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

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