// COOLNEWS

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Stellar Abstracts

Membership, Lithium, and Metallicity in the Young Open Clusters IC 2602 and IC 2391: Enlarging the Sample

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We present lithium abundances for ∼50 X-ray selected candidate members of the 30–50 Myr old open clusters IC 2602 and IC 2391. These data enlarge and extend to cooler temperatures previous Li surveys of these clusters by Stauffer et al. (1989) and Randich et al. (1997). We also give for the first time an estimate of the metallicity of the two clusters which turns out to be close to solar. Radial velocity measurements together with Hα chromospheric emission and the presence/absence of other spectroscopic features are used to ascertain the membership status for the sample stars not yet confirmed as cluster members; rotational velocities have also been determined for all sample stars. Stars more massive than ~ 1 $M_\odot$ in both clusters show no sign of significant Li depletion, while lower mass stars are all lithium depleted, with the amount of Li depletion increasing to cooler temperatures. We confirm that the late G and early K stars in IC 2602 present a star-to-star scatter in Li abundances similar to, but not as large as the one in the Pleiades. A scatter is also seen among late–K and M dwarfs. Unlike in the Pleiades and Alpha Per clusters, the scatter among early–K stars in IC 2602 shows only marginal correlation with rotation. Our data suggest that the drop-off of lithium towards lower masses may start at an earlier color in IC 2391 than in IC 2602, but larger cluster samples are needed to confirm this result. In addition, whereas G and early K stars in the two clusters are, on average, more Li rich than their counterparts in the Pleiades, a fraction of the coolest stars, in particular in IC 2391, are as depleted as the lowest-Li Pleiades stars of the same mass. If they continue depleting Li on their way to the main sequence, they are expected to be more Li depleted than the Pleiades at the age of the latter cluster.

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Time-series Photometric Spot Modeling IV. The Multi-periodic K5Ve Binary V833 Tauri

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We analysed all the existing photometric observations of V833 Tau and found long-term variability on time scales of ≈70 years, 6.5 years and 2.4 years. Using V and I_C-band data from 1990-2000, we obtained starspot surface distributions from 20 suitable light curves. We found that the spot-area changes generally follow the long-term light variations. Spot temperatures are determined for each of the datasets and an average value of 1230 K $\pm$ 270 K relative to the photosphere is found. This value agrees with previous result from TiO modeling (1330 K $\pm$ 110 K). Small scale spot temperature and area changes are recovered during 1997-1999, that we explain with a variable spot/faculae ratio. A powerful flare in $UBV(RI)_C$ was observed in 1993 November. A 10,000 K fit yielded a total emitted flare energy of more than 10^{34} ergs from an area of about 1.3% of the stellar surface, 60% of it in the $V(RI)_C$ bands. The flare characteristics are compared to another, 100-times smaller flare observed earlier in 1983.

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Levels of Coronal and Chromospheric Activity of Late-type Stars and Various Kinds of Dynamo Waves

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The X-ray emission of the F, G and K stars with the investigated chromospheric activity in the HK Project is analysed. It is shown that stars with irregular long-term chromospheric variability possess more powerful coronae, while stars with a cyclic activity are characterized by relatively low X-ray luminosities and their ratios to the bolometric ones. From the point of view of the $\alpha - \Omega$ dynamo theory, this means that features of a magnetic field enhancement in a convective shell vary significantly in passing from small dynamo numbers to large ones. Due to a strong dependence of both the dynamo number and the Rossby number on rotational velocities of stars, the former correlations of activity parameters versus the Rossby number do not contradict to our conclusions. This analysis allows us to obtain the first reliable conclusions on a niche of the solar activity among physical processes on late-type stars.

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Dusty Debris Around Solar-Type Stars: Temporal Disk Evolution

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Using ISO-ISOPHOT we carried out a survey of almost 150 stars to search for evidence of emission from dust orbiting young main sequence stars, both in clusters and isolated systems. Over half of the detections are new examples of dusty stellar systems, and demonstrate that such dust can be detected around numerous stars older than a few $\times 10^6$ years. Fluxes at 60 μm and either 90 or 100 μm for the new excess sources together with improved fluxes for a number of IRAS-identified sources are presented. Analysis of the excess luminosity relative to the stellar photosphere shows a systematic decline of this excess with stellar age consistent with a power law index of -2.

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On the Determination of the Light Curve Parameters of Detached Active Binaries. I. The Prototype RS Canum Venaticorum

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Photospheric cool spots are responsible for wave-like distortions observed in the wide-band light curves of close active binaries. They affect the determination of the photometric parameters in eclipsing systems making it necessary to accurately modelling the spot effects in order to estimate the true luminosity ratio, the fractionary radii and the inclination of the orbital plane in a consistent way. We address such a problem for the prototype active binary RS Canum Venaticorum, for which the availability of a long-term and accurate series of light curves allows us to minimize the starspot effects on the estimation of the quoted parameters. We have analysed the available light curve sequence by using a new parallel code we specifically designed for such an application by solving simultaneously for the system parameters and spot configuration. The uniqueness and stability problems related to the spot mapping are solved by means of a regularization approach, following the method described by Lanza et al. (1998). We evaluate the best set of photometric parameters and their confidence levels by using a statistical method based on the total χ^2 criterion applied to the solution of the entire light curve sequence. The advantages offered by our approach include simplicity and generality with respect to other commonly used methods based on the covariance matrix. We discuss the quantitative effects of the starspots on the estimation of the parameters and compare our method and results with those of other authors. As an application of the derived results, we study the position of the components of RS CVn on the H-R diagram and compare them with computed evolutionary tracks. We find that the position of the primary component is compatible only by assuming a trigonometric parallax of ~ 8.2 mas, i. e., at the lower boundary of the confidence interval given by Hipparcos. Conversely, the effective temperature of the cooler component turns out to be $\sim 5\%$ smaller than expected on the basis of its radius. The comparison with evolutionary tracks also yields an estimate of $\log \tau \simeq 9.41$ years for the age of the system. Moreover, we address the high precision with which the inclination of the orbital plane can be estimated in eclipsing systems, despite the presence of an intense starspot activity. This opens the interesting possibility of detecting precessional motions in young RS CVn binaries, the spin angular momenta of which are not aligned yet with that of the orbital motion. Accepted by A&A

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I. UBV Photometry of Selected Members of the Pleiades and Alpha Persei Clusters in 1999.

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The rotational brightness variations in magnetically active stars are due to the combined light contribution of cool spots and bright faculae on the stellar photosphere. The amplitude of the rotational brightness variations can be used to probe the dependence of the amount of photospheric magnetic fields associated to such inhomogeneities on global stellar parameters such as the rotation rate. However, the upper envelope of the amplitude values must be considered, since the rotational modulation amplitude represents a lower limit of the spots and faculae coverage, being their visibility modulation reduced by several factors.
In order to determine accurately the maximum amplitude upper envelope and its dependence on global stellar parameters a program of photometric monitoring of ultra fast rotating active members of the Pleiades and Alpha Persei star clusters was undertaken in the fall of 1999. Light curves and period determinations of 21 target stars are presented as result from the first observing season. The newly determined values of amplitudes of the brightness variations versus rotation period have values as expected based on previous results.

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Lithium in the Coma Berenices Open Cluster

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Lithium abundances, radial velocities, and rotational velocities are reported for 20 candidate F, G and K stars of the sparse Coma Berenices open cluster. All the stars are proper-motion selected, and our radial velocities support the membership credentials of at least 12 of the candidates. Combining our data with that in the literature, we have a close-to-complete census of Li abundances for late-type stars with M_V <5.8. These data show that the Li-depletion pattern in Coma Ber is similar, but not identical, to that in the Hyades cluster, which has a similar age but higher metallicity. Several Coma Ber F stars have suffered significantly more Li depletion than their counterparts in the Hyades. The G and early-K stars of Coma Ber have undergone less Li depletion than those of the Hyades, but much more than that predicted by standard evolutionary models featuring only convective mixing. This provides strong evidence for additional mixing and Li depletion operating in these stars during their first 400Myr on the main sequence, amounting to 0.3 dex at 6000K and rising to 0.8-1.2 dex at 5400 K. We find that 4 of the radial-velocity non-members are among a small number of low-mass stars which were previously reported as part of an extra-tidal moving group associated with the Coma Ber cluster. As a result, we now find that the luminosity function of this moving group is indistinguishable from that of the central cluster. It is uncertain whether there may be a significant number of stars with even lower masses among the moving group.

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Simultaneous Observations of Variability at all Atmospheric Levels of V824 Ara (HD 155555)

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We conducted a multiwavelength campaign observing V824 Ara (HD 155555, G5 IV + K0 IV-V) continuously throughout one complete orbital cycle (~1.7 days) in early May 1996. At the core of this campaign were observations using the GHRS on HST. In all, about 48,000 spectra, many in rapid readout mode, were obtained with the GHRS covering the C IV, Mg II, and Fe XXI wavelength regions at 11-15 separate phases. Simultaneous observations were made with the EUVE. Radio observations (3.5 & 6 cm) were conducted at the Australian Telescope, while ground-based visual spectroscopic and photometric observations were made at ESO, CTIO, AAT, and SAAO. Additional ground-based observations were obtained before, during, and after the campaign. Our primary intent was to obtain a 3-D model of the atmosphere, extending from the photosphere to the corona. Variability was clearly detected including several flares observed in the HST, EUVE, and radio data. We present results from modeling the ultraviolet transition region lines using an anisotropic macroturbulence model. Previous studies of transition region lines in late-type active stars have used multiple gaussians to fit the observed line profiles, adding additional, broad components to account for the extended wings observed in several active systems including V711 Tau (HR 1099). This broad component has been interpreted as arising from the continuous presence of microflaring. We demonstrate that anisotropic macroturbulence models can also explain the observed Mg II profiles.

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Quiescent and Flare Analysis for the Chromospherically Active Star Gl 355 (LQ Hya)

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We discuss ROSAT and ASCA observations of the young active star Gl 355. During the ROSAT observation a strong flare was detected with a peak flux more than an order of magnitude larger than the quiescent level. Spectral analysis of the data allows us to study the temperature and emission measure distribution, and the coronal metal abundance, for the quiescent phase and, in the case of ROSAT, also during the evolution of the flare. The global coronal metallicity $Z/Z_{\odot} \sim 0.1$ derived from both ROSAT and ASCA data is much lower than solar and presumably also much lower than the photospheric abundance expected for this very young star. The temperature structure of the quiescent corona was about the same during the various observations, with a cooler component at $T_1 \sim 7$ MK and a hotter component (to which only ASCA was sensitive) at $T_2 \sim 20$ MK. During the flare, the low temperature component remained approximately constant and equal to the quiescent value, hile the high-temperature component was the only one that varied. We have modeled the flare with the hydrodynamic-decay sustained-heating approach of Reale at al. (1997) and we have derived a loop semi–length of the order of ~ 1.5 stellar radii, i.e. much larger than the dimensions of flares on the Sun, but comparable with the typical dimensions inferred for other stellar flares. We have compared the derived loop size with that estimated with a simpler (but physically inconsistent) approach, finding that for this, as well for several other stellar flares, the two methods give comparable loop sizes. Possible causes and consequences of this result are discussed.

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Solar Abstracts

Was One Sunspot Cycle Lost in Late XVIII Century?

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We suggest that one solar cycle was lost in the beginning of the Dalton minimum because of sparse and partly unreliable sunspot observations. So far this cycle was combined with the preceding activity to form the exceptionally long solar cycle #4 in 1784-1799, leading to an irregular phase evolution of sunspot activity (known as a phase catastrophe) and other problems. We reanalyze the available group sunspot numbers and suggest that solar cycle #4 was in fact a superposition of two cycles: a normal cycle in 1784-1793 ending at the start of the Dalton minimum and a new weak cycle in 1793-1800 which was the first full cycle within the Dalton minimum. Including the new cycle resolves the problems mentioned above and leads to a consistent view of sunspot activity around the Dalton minimum. Moreover, it will restore the Gnevyshev-Ohl rule of cycle pairing throughout the 400-year interval of sunspot observations.

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Prolateness of the Solar Tachocline Inferred From Latitudinal Force Balance in an MHD Shallow Water Model

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Motivated by recent helioseismic observations concerning solar tachocline shape and thickness, and by the theoretical development of MHD shallow-water equations for the tachocline, we compute the prolateness of the tachocline using an MHD shallow water model in which the shape and thickness are determined from latitudinal force balance equation. We show that a strong toroidal magnetic field stored at or below the overshoot part of the tachocline leads to a pile-up

of fluid at high latitude due to the poleward magnetic curvature stress which has to be balanced by an equatorward latitudinal hydrostatic pressure gradient. For toroidal fields of solar amplitude (∼100 kG), results for differentially rotating and uniformly rotating tachoclines are almost the same. In contrast, the unmagnetized differentially rotating tachocline would always be weakly oblate.

We propose that a strong toroidal field in the overshoot part of the tachocline should tend to suppress the overshooting, thereby increasing the magnetic storage capacity of the layer, since the stratification there should become more subadiabatic. We illustrate the effect of this process on the shape and thickness of the layer, by assuming its effective gravity is a function of field strength.

If toroidal fields are concentrated in relatively narrow bands which migrate toward the equator with the advance of the sunspot cycle, then they should be accompanied by a 'thickness front' advancing at the same rate. Applying our model to the prolateness estimate of Charbonneau et al. Yield toroidal fields of 60-150 kG in the overshoot layer, consistent with other considerations. Their prolateness in the radiative part of the tachocline would require ∼600 kG fields to be present.

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Flux-Transport Dynamos with Alpha-Effect From Global Instability of Tachocline Differential Rotation; A Solution for Magnetic Parity Selection in the Sun

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We propose here an $\alpha\Omega$ flux-transport dynamo driven by a tachocline α-effect, produced by the global hydrodynamic instability of latitudinal differential rotation in the tachocline as calculated using a shallow-water model. Growing, unstable shallow-water modes propagating longitudinally in the tachocline create alternate vortices which correlate with upward/downward radial motion of top boundary, associated with convergence/divergence of the disturbance flow to produce a longitude-averaged net kinetic helicity, and hence an αeffect. We show that a flux-transport dynamo driven by a tachocline αeffect is equally successful as a Babcock-Leighton flux-transport dynamo in reproducing many large-scale solar cycle features, including the most difficult feature of phase relationship between the subsurface toroidal field and surface radial field. In view of the success of flux-transport dynamos, with the αeffect being either at the surface or in the tachocline, we argue that the solar dynamo should be considered to involve three basic processes, rather than two (αeffect and Ωeffect only). The third important process is the advective transport of flux by meridional circulation. In reality, both αeffects (Babcock-Leighton type and tachocline αeffect) are likely to exist, but it is hard to estimate their relative magnitudes. We show, by extending the simulation in a full spherical shell model that a flux-transport dynamo driven by a tachocline αeffect selects toroidal field that is antisymmetric about the equator, while a Babcock-Leighton flux-transport dynamo selects symmetric toroidal field. Since our present Sun selects antisymmetric fields, we argue that tachocline αeffect must be more important than a Babcock-Leighton αeffect.

Submitted to ApJ

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"Shallow Water" MHD Waves in the Solar Tachocline

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This Letter discusses waves in a rotating magnetized fluid layer, governed by "shallow water" magnetohydrodynamics. Such waves likely exist in the solar tachocline, and we focus on this application. A dispersion relation is derived, giving two branches of waves: Alfvén and magneto-gravity waves can propagate without change of shape. However, if the Coriolis force is absent, as on the equator of the tachocline, finite magneto-gravity waves steepen and develop singularities in a time τ_s. It is shown that τ_s increases monotonically with the ambient magnetic field strength.

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Analysis of Hydrodynamic Stability of Solar Tachocline Latitudinal Differential Rotation Using a Shallow-Water Model

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We examine the global, hydrodynamic stability of solar latitudinal differential rotation in a “shallow-water” model of the tachocline. Charbonneau, Dikpati, and Gilman (1999) have recently shown that 2D disturbances are stable in the tachocline (which contains a pole-to-equator differential rotation $s < 18\%$). In our model, the upper boundary of the thin shell is allowed to deform in latitude, longitude, and time, thus including simplified 3D effects. We examine the stability of differential rotation as a function of the effective gravity of the stratification in the tachocline. High effective gravity corresponds to the radiative part of the tachocline; for this case, the instability is similar to the strictly 2D case (appearing only for $s \geq 18\%$), driven primarily by the kinetic energy of differential rotation extracted through the work of Reynolds stress. For low effective gravity, which corresponds to the overshoot part of the tachocline, a second mode of instability occurs, fed again by the kinetic energy of differential rotation which is primarily extracted by additional stresses and correlations of perturbations arising in the deformed shell. In this case, instability occurs for differential rotation as low as about 11% between equator and pole. If this mode occurs in the Sun, it should destabilize the latitudinal differential rotation in the overshoot part of the tachocline, even without a toroidal field.

For the full range of effective gravity, the vorticity associated with the perturbations, coupled with radial motion due to horizontal divergence/convergence of the fluid, gives rise to a longitude-averaged, net kinetic helicity pattern, and hence a source of α-effect and the latitudinal and radial gradients of rotation.

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Dual Flows and Oscillations in the Sunspot Transition Region

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New knowledge about sunspot transition region lines that deviate significantly from a Gaussian shape are presented. Attention is given to ‘multiple flows’, a line profile phenomenon where two or more distinct velocities are observed within the same spatial resolution element. We observe line profiles that are well represented by two Gaussian line components in the N v λ 1242 and O v λ629 lines and introduce the notation ‘dual flow’. We have detected transition region oscillations in one of the line components in the dual flow events.

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Thermal Relaxation of Very Small Solar Magnetic Structures in Intergranules: A Process that Produces kG Magnetic Field Strengths

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The equilibrium configuration of very small magnetic fluxtubes in an intergranular environment automatically produces kG magnetic field strengths. We argue that such process takes place in the Sun and complements the convective collapse (CC), which is traditionally invoked to explain the formation of kG magnetic concentrations in the solar photosphere. In particular, it can concentrate the very weak magnetic fluxes revealed by the new IR spectro-polarimeters, for which the operation of the CC may have difficulty. As part of the argument, we show the existence of solar magnetic features of very weak fluxes yet concentrated magnetic fields (some 3×10^{16} Mx and 1500 G).

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Spatial Analysis of Solar Type III Events Associated with Narrow Band Spikes at Metric Wavelengths

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The spatial association of narrow band metric radio spikes with type III bursts is analyzed. The analysis addresses the question of a possible causal relation between the spike emission and the acceleration of the energetic electrons causing the type III burst. The spikes are identified by the Phoenix-2 spectrometer (ETH Zurich) from survey solar observations in the frequency range from 220 MHz to 530 MHz. Simultaneous spatial information was provided by the Nançay Radioheliograph (NRH) at several frequencies. Five events were selected showing spikes at one or two and type III bursts at two or more Nançay frequencies. The 3–dimensional geometry of the single events has been reconstructed by applying different coronal density models. As a working hypothesis it is assumed that emission at the plasma frequency or its harmonic is the responsible radiation process for the spikes as well as for the type III bursts. It has been found that the spike source location is consistent with the backward extrapolation of the trajectory of the type III bursts, tracing a magnetic field line. In one of the analyzed events, type III bursts with two different trajectories originating from the same spike source could be identified. These findings support the hypothesis that narrow band metric spikes are closely related to the acceleration region.

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G-band Spectral Synthesis in Solar Magnetic Concentrations

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Narrow band imaging in the G-band is commonly used to trace the small magnetic field concentrations of the Sun, although the mechanism that makes them bright has remained unclear. We carry out LTE syntheses of the G-band in an assorted set of semi-empirical model magnetic concentrations. The syntheses include all CH lines as well as the main atomic lines within the band-pass. The model atmospheres produce bright G-band spectra having many properties in common with the observed G-band bright points. In particular, the contrast referred to the quiet Sun is about twice the contrast in continuum wavelengths. The agreement with observations does not depend on the specificities of the model atmosphere, rather it holds from single fluxtubes to MIcro-Structured Magnetic Atmospheres. However, the agreement requires that the real G-band bright points are not spatially resolved, even in the best observations. Since the predicted G-band intensities exceed by far the observed values, we foresee a notable increase of contrast of the G-band images upon improvement of the angular resolution. According to the LTE modeling, the G-band spectrum emerges from the deep photosphere that produces the continuum. Our syntheses also predict solar magnetic concentrations showing up in continuum images but not in the G-band . Finally, we have examined the importance of the CH photo-dissociation in setting the amount of G-band absorption. It turns out to play a minor role.

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High Frequency Oscillations in a Solar Active Region Coronal Loop

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The Solar Eclipse Corona Imaging System (SECIS) was used to record high-cadence observations of the solar corona during the total solar eclipse of 11th August 1999. During the 2 min 23.5 s of totality, 6364 images were recorded simultaneously in each of two channels: a white light channel, and the Fe XIV (5303 Å) 'green line' channel (T $\sim$ 2MK). We report initial results from the SECIS experiment, including the discovery of a 6 sec intensity oscillation in an active region coronal loop.

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A Nanoflare Heating Model for the Quiet Solar Corona

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The energy input into the lower solar corona by flare evaporation events has been modeled according to the available observations for quiet regions. The question is addressed whether such heating events can provide the observed average level of the coronal emission measure and thus of the observed flux of extreme ultraviolet (EUV) and X-ray emission without contradicting the observed average power spectrum of the emission measure, the typical emission measure variations observed for individual pixels and the observed flare energy distribution. As the assumed flare height influences the derived flare energy, the mathematical foundations of nanoflare distributions and their conversion to different height assumptions are studied first. This also allows a comparison with various published energy distributions differing in height assumptions and to relate the observations to the input parameters of the heating model. An analytic evaluation of the power spectrum yields the relationship between the average time profile of nanoflares (or microflares), assumed to be self-similar in energy, and the power spectrum. We find that the power spectrum is very sensitive to the chosen time profile of the flares. Models are found by numerical simulation that fit all available observations. They are not unique but severely constrained. We concentrate on a model with a flare height proportional to the square root of the flare area. The existence of a fitting model demonstrates that nanoflare heating of the corona is a viable and attractive mechanism.

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ANNOUNCEMENT

NCAR Report on Coronal Magnetometry

Coronal Magnetometry: A Fesibility Study

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Measurements of components of the vector magnetic field in the solar corona can potentially yield information critical to our understanding of coronal structure, dynamics and heating. In this report we re-examine various techniques for such measurements, in particular those that can be applied outside of active regions, to investigate issues critical to the development of a new "coronal magnetometer", and to lay down some foundations upon which a suitable instrument may be developed for synoptic observations.

The well-known forbidden coronal emission lines of magnetic dipole (M1) character appear to have the highest potential to address outstanding problems in coronal physics, especially those related to the storage and release of magnetic free energy. Measurements of the full Stokes vector of M1 lines can constrain *both* the line-of-sight (LOS) field strength, $B_{\|}$, through the **longitudinal Zeeman effect** seen in Stokes V profiles, *and* the direction of the vector field projected onto the plane-of-the-sky (POS), through the analysis of **resonance scattering**-induced linear polarization seen in Stokes Q and U, in the so-called "strong field" regime of the Hanle effect. Such measurements can, coupled with additional data and models, reveal information on coronal magnetic fields, potentially including current systems, unobtainable by other means available now or in the near future.

Measuring the weak, Zeeman-induced Stokes V signal presents the greatest observational challenge. Recent work at the NSO Evans coronograph succeeded in detecting convincingly the Zeeman V signal in Fe XIII 1.0746 μm. A more dedicated instrument designed to detect this effect from the outset will have (in principle) little trouble in measuring the linearly polarized signal from the resonance scattering process. The major obstacle is to account for cross-talk in V induced by the dominant (by a factor of 10^2) linear polarization signal.

Both effects can in principle be studied with a single coronagraphic instrument. Based upon simulations of the Stokes profiles, we argue that any new instrument must be able to measure $\frac{V}{I}$ profiles to 1 part in 10^4, and it should span wavelengths from 1.0746 μm (the wavelength of a line of Fe XIII) with capability extending ultimately to 4 μm (to include lines of Mg VIII and Si IX), and down to 0.5303 μm (Fe XIV). This wavelength range points to a reflecting coronagraph. We argue that first priority should be given to build a spectro-polarimeter that includes the 1.0746, 1.0798 μm M1 lines of Fe XIII, the permitted He I lines near 1.0830 μm, and perhaps the Fe XIV 0.5303 μm line in a higher spectral order, keeping longer wavelength capability as a secondary goal. The He I 1.0830 μm line can in principle be used to determine vector magnetic fields through the Hanle effect in prominence fields with $|\vec{B}| \sim 1$ Gauss, and to determine the LOS strength and POS field direction in the "strong field" regime expected in prominences with stronger fields.

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