// COOLNEWS

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Stellar Abstracts

Envelope Tomography of Long-period Variable Stars: I. The Schwarzschild Mechanism and the Balmer Emission Lines

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This paper is the first one in a series devoted to the study of the dynamics of the atmospheres of long-period variable stars. Results from a two-month-long monitoring of the Mira variables RT Cyg and X Oph around maximum light with the ELODIE spectrograph at the Haute-Provence Observatory are presented. The monitoring covers phases 0.80 to 1.16 for RT Cyg and phases 0.83 to 1.04 for X Oph. The cross-correlation profile of the spectrum of RT Cyg with a K0 III mask confirms that the absorption lines of RT Cyg in the optical domain appear double around maximum light. No line doubling was found in the optical spectrum of X Oph around maximum light, indicating that this feature is not common to all long-period variables.

This paper also presents the application to RT Cyg of a new tomographic technique deriving the velocity field across the atmosphere by cross-correlating the optical spectrum with numerical masks constructed from synthetic spectra and probing layers of increasing depths. This technique reveals that both the temporal evolution of the line doubling, and its variation with depth in the atmosphere of RT Cyg, are consistent with the "Schwarzschild scenario". This scenario relates the temporal evolution of the red and blue peaks of the double absorption lines to the progression of a shock wave in the atmosphere.

The temporal evolution of the Balmer Hα, Hβ, Hγ and Hδ emission lines around maximum light is also presented for RT Cyg and X Oph. The velocity variations of Hα and of the absorption lines are discussed in the framework of two competing models for the formation of Balmer emission lines in long-period variable stars.

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H_2 in the 2 Micron Infrared Spectra of Long Period Variables I. Observations

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Up to seven lines in the S branch of molecular hydrogen have been detected in the 2 μm infrared absorption line spectra of long period variables. The H_2 lines show very strong phase dependent changes in velocity, equivalent width, and line profile, with the strongest lines near minimum light. The strength of the H_2 lines also depends on variable type with mira variables having deep lines (at minimum light), SRa variables generally having detectable lines, and the SRb and non-variables having weak to non-detectable lines. In addition H_2 line strengths depend on period and on C/O abundance, with long period (i.e. cool), pure S-type miras having H_2 lines with central depths of up to 80%. The appearance of H_2 lines in the spectra of cool giants is linked with geometrical extension of the atmosphere. The greatly increased strength of the H_2 lines in mira variables is observational evidence of the role of stellar pulsation in greatly extending these stellar atmospheres. Weak emission is seen in H_2 near maximum light in miras. We suggest this is resonant scattering in the spherically extended stellar atmosphere. The significant role of H_2 opacity in the blue is noted.

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Chromospherically Active Stars. XVIII. Sorting Out the Variability of HD 95559 and Gliese 410 = DS Leonis

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We have obtained spectroscopy and photometry of HD 95559 and photometry of Gliese 410 = DS Leonis. HD 95559 consists of a pair of essentially identical K1 V stars, whose orbital period we refine to 1.52599798 $\pm$ 0.00000034 days. The system is photometrically variable with a mean period of 1.5264 $\pm$ 0.0003 days. Despite minimum masses greater than 0.8 solar masses for each component, a search for eclipses proved negative. The lithium abundances of the components of HD 95559 indicate that the system is younger than the Hyades cluster, and its components may even have just arrived on the zero-age main sequence. Gliese 410 = DS Leo is also a photometric variable, but we conclude that the photometric period originally ascribed to this star is an alias of the period for HD 95559. We find periods of 13.99 and 15.71 days for the first and second seasons of observation, respectively. Both HD 95559 and Gliese 410 are BY Draconis variables, with variability resulting from the rotational modulation of starspots. We also find HR 4269, the check star for our photometry of HD 95559 and Gliese 410, to be a variable K4 III with a photometric period of 26.4 days in the first season of observation and periods of 13.96 and 83 days in the second. We suggest that its variability mechanism is radial pulsation, the same as that for M-giant semi-regular variables.

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Simulations of the Photospheric Magnetic Activity and Outer-atmospheric Radiative Losses of Cool Stars Based on Characteristics of the Solar Magnetic Field

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The observed disk-integrated radiative losses from the outer atmospheres of stars with convective envelopes are determined by the distribution of magnetic field over their surfaces. Earlier modeling of the random-walk transport of the solar photospheric magnetic field with the classical Leighton model has given us insight in how field patterns form and evolve on large scales. This paper presents the first comprehensive simulations of the dynamic photospheric magnetic field of the Sun down to the scale of the mixed-polarity network, thus incorporating all flux involved in outer-atmospheric heating. The algorithm incorporates the classical diffusion model, but includes ephemeral regions (which populate the network that contributes significantly to the disk-integrated chromospheric emission), and the early phase of decay of active regions (which is important for the field patterns in very active stars). Moreover, individual flux concentrations are tracked and subjected to collisions and fragmentation, and the flux dispersal is made dependent on the flux contained in the concentrations, as observed on the Sun. The latter modification causes the model to be nonlinear. Tests demonstrate that the new model successfully describes the solar magnetic field.

The model is then used to simulate the field on other cool stars covering several orders of magnitude in activity, and to estimate the surface-averaged radiative losses associated with that field. The stellar extrapolations are based on the statistical properties of solar bipolar regions throughout the cycle. Simulations in which only the frequency of flux emergence is changed to simulate stars of different activity are shown to be consistent with the observed nonlinear relationships between disk-averaged radiative losses from chromospheres and coronae of cool stars. Consequently, the properties of the solar magnetic field from small ephemeral regions up to large active regions are compatible with stellar observations. Stellar observations suggest that those field properties are not the only ones that can explain the flux-flux relationships, however, because also stars with polar spots or persistent active longitudes obey these same flux-flux relationships.

The model is also used to understand how rapidly flux is processed in stellar photospheres in stars with activity patterns like the Sun: the average total absolute magnetic flux $\langle \Phi_* \rangle$ (Mx) at the stellar surface is found to be proportional to the mean rate of flux emergence and cancellation $\langle E_* \rangle$ (Mx/s) within the range from $1/10 \times \langle E_\odot \rangle$ up to $10 \times \langle E_\odot \rangle$, where $\langle E_\odot \rangle$ is the flux-injection rate for the active Sun. This linearity is primarily a consequence of an activity-dependent change in the shape of the flux histogram for emerging bipoles. This change reflects that active regions and ephemeral regions have a different dependence on dynamo strength. The implications of the results of the simulations for the dynamo and for the relationship between activity and stellar rotation are discussed.

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On the Variation of the Initial Mass Function

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A universal initial mass function (IMF) is not intuitive, but so far no convincing evidence for a variable IMF exists. The detection of *systematic variations* of the IMF with star-forming conditions would be the *Rosetta Stone* for star formation.

In this contribution an average or Galactic-field IMF is defined, stressing that there is evidence for a change in the power-law index at only two masses: near $0.5\,M_\odot$ and $0.08\,M_\odot$. Using this supposed universal IMF, the uncertainty inherent to any observational estimate of the IMF is investigated, by studying the scatter introduced by Poisson noise and the dynamical evolution of star clusters. It is found that this apparent scatter reproduces quite well the observed scatter in power-law index determinations, thus defining the *fundamental limit* within which any true variation becomes undetectable. The absence of evidence for a variable IMF means that any true variation of the IMF in well studied populations must be smaller than this scatter.

Determinations of the power-law indices α are subject to systematic errors arising mostly from unresolved binaries. The systematic bias is quantified here, with the result that the single-star IMFs for young star-clusters are systematically steeper by $\Delta\alpha \approx 0.5$ between 0.1 and $1\,M_\odot$ than the Galactic-field IMF, which is populated by, on average, about 5 Gyr old stars. The MFs in globular clusters appear to be, on average, systematically flatter than the Galactic-field IMF (Piotto & Zoccali 1999; Paresce & De Marchi 2000), and the recent detection of ancient white-dwarf candidates in the Galactic halo and absence of associated low-mass stars (Méndez & Minniti 2000; Ibata et al. 2000) suggests a radically different IMF for this ancient population. Star-formation in higher-metallicity environments thus appears to produce relatively more low-mass stars. While still tentative, this is an interesting trend, being consistent with a systematic variation of the IMF as expected from theoretical arguments.

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or as astro-ph/0009005

Modelling CO Emission from Mira's Wind

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We have modelled the circumstellar envelope of *o* Ceti (Mira) using new observational constraints. These are obtained from photospheric light scattered in near-IR vibrational-rotational lines of circumstellar CO molecules at $4.6\,\mu$m: absolute fluxes, the radial dependence of the scattered intensity, and two line ratios. Further observational constraints are provided by ISO observations of far-IR emission lines from highly excited rotational states of the ground vibrational state of CO, and radio observations of lines from rotational levels of low excitation of CO. A code based on the Monte-Carlo technique is used to model the circumstellar line emission.

The vibrational-rotational lines are sensitive to the radiation field, whereas the pure rotational lines, such as the rotational lines of low excitation measured at radio wavelengths and the rotational lines from highly excited states observed with ISO, are usually more sensitive to the temperature structure. These rotational lines have been the prime probe in most earlier investigations.

We find that it is possible to model the radio and ISO fluxes, as well as the highly asymmetric radio-line profiles, reasonably well with a spherically symmetric and smooth stellar wind model. However, it is not possible to reproduce the observed NIR line fluxes consistently with a 'standard model' of the stellar wind. This is probably due to incorrectly specified conditions of the inner regions of the wind model, since the stellar flux needs to be larger than what is obtained from the standard model at the point of scattering, i.e., the intermediate regions at approximately $100-400\,R_*$ (2"-7") away from the star. Thus, the optical depth in the vibrational-rotational lines from the star to the point of scattering has to be decreased. This can be accomplished in several ways. For instance, the gas close to the star (within approximately 2") could be in such a form that light is able to pass through, either due to the medium being clumpy or by the matter being in radial structures (which, further out, developes into more smooth or shell-like structures). Further observations of the gas in the stellar wind close to Mira are required to resolve this problem.

The model circumstellar envelope, which reproduces the observables reasonably well, has a mass-loss rate of
$2.5\times10^{-7}\,M_\odot\,yr^{-1}$, and a turbulent velocity of $1.5\,km\,s^{-1}$, given a terminal expansion velocity of the wind of $2.5\,km\,s^{-1}$.

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The Coronal Metallicity of the Intermediate Activity Dwarf ξ Boo A

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EUVE spectra from a 270 ks observation of the intermediate activity star ξ Boo A (G8 V) have been analysed in order to determine the metallicity of its coronal plasma. This analysis was based on a new method that used both the EUVE spectroscopic and photometric (Deep Survey) data, together with theoretical model spectra. By comparison of observed and synthetic spectra computed using the CHIANTI database, we estimated that about 20 % of the observed line flux is not accounted for in the theoretical model. Allowing for the "missing lines" in our analysis, we obtain a coronal metallicity for ξ Boo A of [M/H]= $0.1\pm^{0.2}_{0.15}$. This is slightly higher than the photospheric metallicity of [M/H]= -0.15 ± 0.05 and lends support to the results of our earlier analysis of the same spectral data that indicated that coronal abundances of elements with low first ionization potentials (FIPs) are systematically higher than those of elements with high FIPs. These results, coupled with other evidence, imply that stars of intermediate activity level—stars more active than the Sun but significantly less active than the most active single and binary stars—do not suffer from any depletion of metals in their coronae as some coronal metallicities estimated for more active stars have appeared to suggest. The observation of a solar-like FIP Effect on ξ Boo A adds support to the notion that stars of intermediate activity level have coronae characterised by a high surface coverage of bright solar-like active regions.

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On Stellar Coronae and Solar Active Regions

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Based on *Yohkoh* SXT observations of the Sun near peak activity level obtained on 6 January 1992, we search for coronal structures that have emission measure distributions $EM(T)$ that match the observed stellar coronal emission measure distributions derived for the intermediate activity stars ϵ Eri (K2 V) and ξ Boo A (G8 V) from EUVE spectroscopic observations. We find that the temperatures of the peaks of the observed stellar distributions $EM(T)$, as well as their slopes in the temperature range $6.0 \lesssim \log T \lesssim 6.5$, are very similar to those obtained for the brightest of the solar active regions in the 6 January 1992 SXT images. The observed slopes correspond approximately to $EM \propto T^\beta$ with $\beta \sim 4$, which is much steeper than predicted by static, uniformly heated loop models. Plasma densities in the coronae of ϵ Eri and ξ Boo A are also observed to be essentially the same as the plasma densities typical of solar active regions. These data provide the best observational support yet obtained for the hypothesis that solar-like stars up to the activity levels of ϵ Eri (K2 V) and ξ Boo A are dominated by active regions similar to those observed on the Sun. The surface filling factor of bright active regions needed to explain the observed stellar emission measures is approximately unity. We speculate on the scenario in which small-scale "nanoflares" dominate the heating of active regions up to activity levels similar to those of ϵ Eri (K2 V) and ξ Boo A. At higher activity levels still, the interactions of the active regions themselves may lead to increasing flaring on larger scales that is responsible for heating plasma to the observed coronal temperatures of $T \gtrsim 10^7$ K on very active stars. Observations of X-ray and EUV light curves using more sensitive instruments than are currently available, together with determinations of plasma densities over the full range of coronal temperatures (10^6 to 10^7 K and higher), will be important to confirm flare heating hypotheses and to elicit further details concerning coronal structures at solar-like active region temperatures ($T \lesssim 5\,10^6$ K) and the temperatures that characterise the most active stars ($T \gtrsim 10^7$ K).

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Evidence for Long-period Planet Orbiting Epsilon Eridani

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High precision radial velocity (RV) measurements spanning the years 1980.8–2000.0 are presented for the nearby (3.22 pc) K2 V star ϵ Eri. These data, which represent a combination of six independent data sets taken with four different telescopes, show convincing variations with a period of $\approx$ 7 yrs. A least squares orbital solution using robust estimation yields orbital parameters of period, $P = 6.9$ yrs, velocity K-amplitude = 19 m s^{-1}, eccentricity $e = 0.6$, projected companion mass $M \sin i = 0.86\ M_{Jupiter}$, and semi-major axis $a_2 = 3.3$ AU. Ca II H&K S-index measurements spanning the same time interval show significant variations with periods of 3 and 20 yrs, yet none at the RV period. If magnetic activity were responsible for the RV variations then it produces a significantly different period than is seen in the Ca II data. Given the lack of Ca II variation with the same period as that found in the RV measurements, the long-lived and coherent nature of these variations, and the high eccentricity of the implied orbit, Keplerian motion due to a planetary companion seems to be the most likely explanation for the observed RV variations. The wide angular separation of the planet from the star (approximately 1 arc-second) and the long orbital period make this planet a prime candidate for both direct imaging and space-based astrometric measurements.

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An Empirical Procedure to Estimate Distances to Stellar Clusters

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A most desirable feature of a standard candle to estimate astronomical distances is robustness against changes in metallicity and age. It is argued that the radii of main sequence stars with spectral types from solar to A0 show predictable changes with metallicity, and detectable changes with evolution. Such stars populate the solar neighborhood, and therefore benefit from measurements of angular diameters. Also, reliable determinations of their masses and radii are available from observations of eclipsing binaries. Three empirical relationships are defined and suggested for estimating distances to dwarfs from only BVK photometry. Comparison with *Hipparcos* trigonometric parallaxes shows that the method provides errors of about 15 % for a particular star, which can be reduced to roughly 1.5 % when applied to young clusters (age $<\sim 1-2$ Gyr) with ~ 100 stars of the appropriate spectral types. If reddening is unknown, main sequence stars with effective temperatures close to 8000 K can constrain it, although an estimate of $\mathcal{R} \equiv \mathrm{A}(V)/E(B-V)$ is required.

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Solar Abstracts

Sunspot Plumes and Flow Channels

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It is well known that sunspots are dark. This statement is not correct in the sunspot atmosphere between the chromosphere and the corona, where sunspots often are brighter than their surroundings. The brightest feature in the sunspot transition region is called a sunspot plume. Not all sunspots contain a plume. We find that 20 out of 21 sunspots show a plume when one magnetic polarity dominates the sunspot region out to a distance of 50 arc-sec from the sunspot. Most sunspots show downflows that exceed 25 km s^{-1} in the sunspot plumes at temperatures close to 250 000 K. This downflow is not maintained by inflow from the corona, but by gas at transition region temperatures, streaming in flow channels from locations well outside the sunspot. We suggest that this inflow is a

necessary requirement for the sunspot plume to occur and present a working hypothesis for the origin of sunspot plumes.

This paper is the first thorough spectral analysis of sunspot plumes. It is based on simultaneous observations of ten or six EUV emission lines in 42 sunspot regions with the Coronal Diagnostic Spectrometer - CDS on the Solar and Heliospheric Observatory - SOHO. The line profiles are studied in detail with another SOHO instrument, the Solar Ultraviolet Measurements of Emitted Radiation - SUMER.

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Catastrophic Cooling and High-speed Downflow in Quiescent Solar Coronal Loops Observed with TRACE

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Observations with the Transition Region and Coronal Explorer, TRACE, show frequent catastrophic cooling and evacuation of quiescent solar coronal loops over active regions. We analyze this process using image sequences taken in pass bands showing plasma from a few million degrees down to less than 100,000 K, taken at a cadence of 90 s. The loop evacuation often occurs after plasma high in the corona has cooled to transition-region or even chromospheric temperatures. The cooling loops frequently show Lyman α and C IV emission developing initially near the loop tops; later, that cool plasma usually slides down on both sides of the loop. The relatively cool material often forms clumps that move at speeds of up to 100 km/s. The downward acceleration is no more than $80\,\mathrm{m/s^2}$, less than 1/3rd of the surface gravity. Cooling appears to progress with delays of the order of up to 10^3 s between thin, neighboring strands within flux bundles with cross sections of at least 1-2 Mm, so that hot and cool loops are transiently outlined at essentially the same location. The falling material at temperatures of ≤ 0.1 MK shows no evidence of loop braiding on scales above the resolution of $\sim$ 1 Mm; loop cross sections appear independent of height. Existing numerical models suggest that the observed catastrophic loop-top cooling in non-flaring conditions can occur if the loop heating precipitously drops by 1.5 orders of magnitude or more, first and most strongly high in the corona. Using order-of-magnitude geometrical arguments, we estimate that loop bundles in the interior of an active region undergo catastrophic cooling once every 2 days, while in a decayed bipolar region that time interval is approximately a week.

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Persistent 22-year Cycle in Sunspot Activity: Evidence for a Relic Solar Magnetic Field

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We use the recently presented group sunspot number series to show that a persistent 22-year cyclicity exists in sunspot activity throughout the entire period of about 400 years of direct sunspot observations. The amplitude of this cyclicity is about 10% of the present sunspot activity level. A 22-year cyclicity in sunspot activity is naturally produced by the 22-year magnetic polarity cycle in the presence of a relic dipole magnetic field. Accordingly, a persistent 22-year cyclicity in sunspot activity gives an evidence for the existence of such a relic magnetic field in the Sun. The stable phase and the roughly constant amplitude of this cyclicity during times of very different sunspot activity level strongly support this interpretation.

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Heliospheric Modulation of Cosmic Rays and Solar Activity During the Maunder Minimum

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Modern models and direct cosmic ray experiments deal with heliospheric modulation of cosmic rays only during the recent times of rather high overall solar activity level. On the other hand, the question of cosmic ray modulation during the exceptional conditions of very quiet heliosphere is important. In the present paper we compare the variations of cosmic ray intensity with solar and auroral activity during the Maunder minimum (1645-1715) when the Sun was extremely quiet. We use the newly presented group sunspot number series as a measure of early solar activity, the auroral observations in central Europe as an indicator of transient phenomena in the inner heliosphere, and the radiocarbon data as a proxy of cosmic ray intensity. We find that both cosmic ray intensity and auroral activity closely follow the dominant 22-year cyclicity with sunspot activity during the Maunder minimum. Moreover, the strict antiphase between the 22-year variation of cosmic ray intensity and sunspot activity suggests that the 22-year variation in cosmic ray intensity can be explained by the diffusion-dominated terms of cosmic ray modulation without significant drift effects. We also discuss the possible origin of the behavior of the ^{10}Be data which is different from all other parameters during the Maunder minimum.

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Brown Dwarf Abstracts

Deuterium-burning in Substellar Objects

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We consider the depletion of primordial deuterium in the interior of substellar objects as a function of mass, age and absolute magnitude in several photometric passbands. We characterize potential spectroscopic signatures of deuterium in the lines of deuterated water HDO. These results will serve as a useful, independent diagnostic to characterize the mass and/or the age of young substellar objects, and to provide an independent age determination of very young clusters. These results can serve to identify objects at the deuterium-burning limit and to confront the theoretical prediction that D-burning is a necessary condition to form star-like objects.

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Atomic Data

CHIANTI - An Atomic Database for Emission Lines Paper 4: Extension to X-ray Wavelengths

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CHIANTI provides a database of atomic energy levels, wavelengths, radiative transition probabilities and electron excitation data for a large number of ions of astrophysical interest. It also includes a suite of Interactive Data Language (IDL) programs to calculate optically thin synthetic spectra and to perform spectral analysis and plasma diagnostics. This database allows the calculation of theoretical line emissivities necessary for the analysis of optically thin emission line spectra.

The first version (1.01) of the CHIANTI database was released in 1996 (Dere et al. 1997). The second version, released in 1999, included continuum emission and data for additional ions (Landi et al. 1999). Both versions of the CHIANTI database have been used extensively by the astrophysical and solar communities to analyze emission line spectra from astrophysical sources.

Now the CHIANTI database has been extended to wavelengths shorter than 50Å by including atomic data for the hydrogen and helium isoelectronic sequences, inner-shell transitions and satellite lines and several other ions. In addition, some of the ions already present in the database have been updated and extended with new atomic data from published calculations.

Submitted to ApJS

CHIANTI is available via ftp or WWW: http://wwwsolar.nrl.navy.mil/chianti.html

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Center for Astrophysics

University of Porto (Portugal)

CAUP accepts applications for **post-doctoral positions** for one year with possible extension up to three years. These are expected to start as soon as possible. The deadline for applications is the **31st of October 2000**.

CAUP is a young Research Institute with a staff of 18 researchers, several Ph.D. students and two Master Programes (involving more than 40 students). Current research projects are in the fields of

- **Stellar Astrophysics**
  - Activity and Variability of Young Stellar Objects, Insterstellar Medium and Circumstellar Material, Modelling of Stellar Winds, Stellar Seismology
- **Cosmology**
  - Clusters of Galaxies, Galactic Evolution, Cosmic Microwave Background Radiation, Simulations of Structure Formation

The Institute is located at the University Campus of Campo Alegre, sharing a new building with the town Planetarium. CAUP has an extensive set of collaborations with international partners on research and teaching projects. For further detailed information please see http://www.astro.up.pt/.

Applicants should forward a curriculum vitae, list of publications, a brief description of past experience and of research interests, a proposal for future research projects at CAUP as well as the name/address/email of three referees.

Inquiries about the positions and CAUP can be directed to

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Porto, 25th September 2000.

Abstract Guidelines

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

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

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

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