COOLNEWS

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Stellar Abstracts

TYC 8380-1953-1: Discovery of an RS CVn Binary Through the *XMM-Newton* Slew Survey

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In this paper we report the discovery of the chromospherically active (RS CVn type) binary TYC 8380-1953-1 through the *XMM-Newton* slew survey and present results of our optical and X-ray follow-up. With a flux limit of 6×10^{-13} erg cm^{-2} s^{-1} in the soft band ($0.2 - 2$ keV), the *XMM-Newton* slew has a similar sensitivity to the *ROSAT* All Sky Survey allowing interesting sources to be identified by their long-term variability. Two different types of stellar sources are detected in shallow X-ray surveys: young stars (both pre-main and main sequence stars) and chromospherically active binaries (BY Dra and RS CVn type systems). The discovery of stars in such surveys and the study of their nature through optical follow-ups is valuable to determine their spatial distribution and scale height in the Galaxy. Our analysis shows that TYC 8380-1953-1 is a double-lined spectroscopic binary with both components having similar spectral type (likely K0/2+K3/5) and luminosity. With a typical coronal temperature for an RS CVn system ($kT \sim$ 1.15 keV) and an X-ray luminosity in the 0.3–10 keV energy band higher than 4×10^{31} erg s^{-1}, TYC 8380-1953-1 lies among the most X-ray luminous RS CVn binaries.

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Magnetic Activity and Differential Rotation in the Young Sun-like Stars KIC 7985370 and KIC 7765135

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We present a detailed study of the two Sun-like stars KIC 7985370 and KIC 7765135, aimed at determining their activity level, spot distribution, and differential rotation. Both stars were discovered by us to be young stars and were observed by the NASA *Kepler* mission.
The fundamental stellar parameters ($v \sin i$, spectral type, $T_{\rm eff}$, $\log g$, and [Fe/H]) were derived from optical spectroscopy by the comparison with both standard-star and synthetic spectra. The spectra of the targets allowed us also to study the chromospheric activity from the emission in the core of hydrogen Hα and CaII infrared triplet (IRT) lines, revealed by the subtraction of inactive templates. The high-precision Kepler photometric data spanning over 229 days were then fitted with a robust spot model. Model selection and parameter estimation are performed in a Bayesian manner, using a Markov chain Monte Carlo method.
Both stars came out to be Sun-like (G1.5 V spectral type) with an age of about 100–200 Myr, based on their lithium content and kinematics. Their youth is confirmed by the high level of chromospheric activity, which is comparable to that displayed by the early G-type stars in the Pleiades cluster. The Balmer decrement and flux ratio of the CaII-IRT lines suggest that the formation of the core of these lines occurs mainly in optically-thick regions that are analogous to solar plages. The spot model applied to the *Kepler* photometry requires at least seven enduring spots in the case of KIC 7985370 and nine spots in the case of KIC 7765135 for a satisfactory fit of the data. The assumption of longevity of the star spots, whose area is allowed to evolve in time, is at the heart of our spot-modelling approach. On both stars the surface differential rotation is Sun-like, with the high-latitude spots rotating slower than the low-latitude ones. We found, for both stars, a rather high value of the equator-to-pole differential rotation ($\mathrm{d}\Omega \approx 0.18$ rad d^{-1}) which is in contrast with the predictions of some mean-field models of differential rotation for fast-rotating stars. Our results are instead in agreement with previous works on solar-type stars and with other models which predict a higher latitudinal shear, increasing with equatorial angular velocity, that can undergo changes along the magnetic cycle.

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For preprints via ftp or WWW: http://arxiv.org/abs/1205.5721

Chemically Tagging the Hyades Supercluster: A Homogeneous Sample of F6-K4 Kinematically-selected Northern Stars

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Stellar kinematic groups are kinematical coherent groups of stars that might have a common origin. These groups are dispersed throughout the Galaxy over time by the tidal effects of both Galactic rotation and disc heating, although their chemical content remains unchanged. The aim of chemical tagging is to establish that the abundances of every element in the analysis are homogeneus among the members. We study the case of the Hyades Supercluster to compile a reliable list of members (FGK stars) based on our chemical tagging analyisis. For a total of 61 stars from the Hyades Supercluster, stellar atmospheric parameters ($T_{\rm eff}$, $\log g$, ξ, and [Fe/H]) are determined using our code called StePar, which is based on the sensitivity to the stellar atmospherics parameters of the iron EWs measured in the spectra. We derive the chemical abundances of 20 elements and find that their [X/Fe] ratios are consistent with Galactic abundance trends reported in previous studies. The chemical tagging method is applied with a carefully developed differential abundance analysis of each candidate member of the Hyades Supercluster, using a well-known member of the Hyades cluster as a reference (vB 153). We find that only 28 stars (26 dwarfs and 2 giants) are members, i.e. that 46 %

of our candidates are members based on the differential abundance analysis. This result confirms that the Hyades Supercluster cannot originate solely from the Hyades cluster.

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CARMA CO($J = 2 - 1$) Observations of the Circumstellar Envelope of Betelgeuse

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We report radio interferometric observations of the $^{12}C^{16}O$ 1.3 mm $J = 2 - 1$ emission line in the circumstellar envelope of the M supergiant α Ori and have detected and separated both the S1 and S2 flow components for the first time. Observations were made with the Combined Array for Research in Millimeter-wave Astronomy (CARMA) interferometer in the C, D, and E antenna configurations. We obtain good $u - v$ coverage (5–280 kλ) by combining data from all three configurations allowing us to trace spatial scales as small as $0''.9$ over a $32''$ field of view. The high spectral and spatial resolution C configuration line profile shows that the inner S1 flow has slightly asymmetric outflow velocities ranging from $-9.0\,\mathrm{km\,s^{-1}}$ to $+10.6\,\mathrm{km\,s^{-1}}$ with respect to the stellar rest frame. We find little evidence for the outer S2 flow in this configuration because the majority of this emission has been spatially-filtered (resolved out) by the array. We also report a SOFIA-GREAT CO($J = 12-11$) emission line profile which we associate with this inner higher excitation S1 flow. The outer S2 flow appears in the D and E configuration maps and its outflow velocity is found to be in good agreement with high resolution optical spectroscopy of K I obtained at the McDonald Observatory. We image both S1 and S2 in the multi-configuration maps and see a gradual change in the angular size of the emission in the high absolute velocity maps. We assign an outer radius of $4''$ to S1 and propose that S2 extends beyond CARMA's field of view ($32''$ at 1.3 mm) out to a radius of $17''$ which is larger than recent single-dish observations have indicated. When azimuthally averaged, the intensity fall-off for both flows is found to be proportional to R^{-1}, where R is the projected radius, indicating optically thin winds with $\rho \propto R^{-2}$.

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SOAP. A Tool for the Fast Computation of Photometry and Radial Velocity Induced by Stellar Spots

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We define and put at disposal SOAP, *Spot Oscillation And Planet*, a software tool that simulates the effect of stellar spots and plages on radial velocimetry and photometry. This paper describes the tool release and provides instructions for its use. We present detailed tests to assess its performance and to validate the suitability of the code with previous computations and real data. We characterize the variations of the radial velocity, line bisector, and photometric amplitude as a function of the main variables: projected stellar rotational velocity, filling factor of the spot, resolution of the spectrograph, linear limb-darkening coefficient, latitude of the spot, and inclination of the star. Finally, we model the spot distributions on the active stars HD166435, TW Hya and HD189733 that reproduces the observations. We show that the software is remarkably fast allowing several evolutions in its capabilities that could be done to study the next challenges in the exoplanetary field connected with the stellar variability.

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The code is available at: http://www.astro.up.pt/soap

The Penn State–Toruń Centre for Astronomy Planet Search Stars. I. Spectroscopic Analysis of 348 Red Giants

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We present basic atmospheric parameters ($T_{\rm eff}$, $\log g$, $v_{\rm t}$ and [Fe/H]) as well as luminosities, masses, radii and absolute radial velocities for 348 stars, presumably giants, from the $\sim$ 1000 star sample observed within the Penn State-Toruń Centre for Astronomy Planet Search with the High Resolution Spectrograph of the 9.2 m Hobby-Eberly Telescope. The stellar parameters (luminosities, masses, radii) are key ingredients in proper interpretation of newly discovered low-mass companions while a systematic study of the complete sample will create a basis for future statistical considerations concerning low-mass companions appearance around evolved low and intermediate-mass stars. The atmospheric parameters were derived using a strictly spectroscopic method based on the LTE analysis of equivalent widths of Fe I and Fe II lines. With existing photometric data and the Hipparcos parallaxes we estimated stellar masses and ages via evolutionary tracks fitting. The stellar radii were calculated from either estimated masses and the spectroscopic $\log g$ or from the spectroscopic $T_{\rm eff}$ and estimated luminosities. The absolute radial velocities were obtained by cross-correlating spectra with a numerical template. We completed the spectroscopic analysis for 332 stars of which 327 were found to be giants. For the remaining 16 stars with incomplete data a simplified analysis was applied. The results show that our sample is composed of stars with effective temperatures ranging from 4055 K to 6239 K, and $\log g$ between 1.39 and 4.78 (5 dwarfs were identified). The estimated luminosities ranging between $\log L/L_{\odot} = -1.0$ and 3 lead to masses ranging from 0.6 to 3.4 $M_{\odot}$. Only 63 stars with masses larger than 2 $M_{\odot}$ were found. The radii of our stars range from 0.6 to 52 $R_{\odot}$ with vast majority between 9-11 $R_{\odot}$. The stars in our sample are generally less metal abundant than the Sun with median [Fe/H] = -0.15. The estimated uncertainties in the atmospheric parameters were found to be comparable to those reached in other studies. However, due to lack of precise parallaxes the stellar luminosi ties and, in turn, the masses are far less precise, within 0.2 $M_{\odot}$ in best cases, and 0.3 $M_{\odot}$ on average.

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Observation and Modelling of Main Sequence Stellar Chromospheres XIX. FIES and FEROS Observations of dM1 Stars

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We present 187 high resolution spectra for 62 different M1 dwarfs from observations obtained with the FIES spectrograph on the Nordic Optical Telescope (NOT) and from observations with the FEROS spectrograph from the European Southern Observatory (ESO) database. We also compiled other measurements available in the literature.

We observed two stars, Gl 745 A and B, with no Ca II line core emission and H_{α} line EWs of only 0.171Å and 0.188Å respectively. We also observed another very low activity M1 dwarf, Gl 63, with an H_{α} line EW of only 0.199Å. These

are the lowest activity M dwarfs ever observed and are of particular interest for the NLTE-radiative transfer modelling of M1 dwarfs.

Thanks to the high S/N ratio of most of our spectra, we were able to measure the Ca II H & K FWHM for most of our stars. We find good correlations between the FWHMs and the mean Ca II line EW for dM1 stars. Then the FWHM seems to saturate for dM1e stars. Our previous models of M1 dwarfs can reproduce the FWHM for dM1e stars and the most active dM1 stars, but fail to reproduce the observations of lower activity M1 dwarfs. We believe this is due to an effect of metallicity. We also investigate the dependence of the H_α line FWHM as a function of its EW. We find that the models globally agree with the observations including subdwarfs, but tend to produce too narrow profiles for dM1e stars.

We re-investigate the correlation between the Ca II line mean equivalent width and the absolute magnitude. With our new data that notably include several M1 subdwarfs, we find a slightly different and better correlation with a slope of -0.779 instead of -0.909. We also re-investigate the variations of the H_α line EW as a function of radius and find that the EW increases continuously with increasing radius. This confirms our previous finding that the level of magnetic activity in M1 dwarfs increases with the radius.

For the first time, we investigate the Wilson-Bappu correlation for a given spectral type. We find a rather linear correlation for stars of absolute magnitude greater than 9.6, but below this value the FWHM seems to saturate. In fact, we show that these Wilson-Bappu type correlations are activity-FWHM correlations and are due to the diminishing column mass of the transition region with decreasing activity level.

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Coronal Activity Cycles in Nearby G and K Stars: XMM-Newton Monitoring of 61 Cygni and α Centauri

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We used X-ray observations of the nearby binaries 61 Cyg A/B (K5V and K7V) and α Cen A/B (G2V and K1V) to study the long-term evolution of magnetic activity in weakly to moderately active G + K dwarfs over nearly a decade and specifically we searched for X-ray activity cycles and related coronal changes. 61 Cyg A shows a regular coronal activity cycle analog to its 7.3 yr chromospheric cycle; its X-ray brightness variations are with a factor of three lower than on the Sun, yet the changes of coronal properties resemble the solar behavior with larger variations occurring in respective hotter plasma components. 61 Cyg B does not show a clear cyclic coronal trend so far, but the X-ray data matches the more irregular chromospheric cycle. Both α Cen stars exhibit significant long-term X-ray variability. α Cen A shows indications for cyclic variability of an order of magnitude with a period of about 12-15 years; the α Cen B data suggests an X-ray cycle with an amplitude of about six to eight and a period of 8-9 years. The sample stars exhibit X-ray luminosities ranging between $L_X < 1 \times 10^{26} - 3 \times 10^{27}$ erg s^{-1} in the 0.2-2.0 keV band and have coronae dominated by cool plasma with variable average temperatures of around 1.0-2.5 MK. We find that coronal activity cycles are apparently a common phenomenon in older, slowly rotating G and K stars. The spectral changes of the coronal X-ray emission over the cycles are solar-like in all studied targets.

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On the Detectability of Star-Planet Interaction

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Magnetic (or tidal) interactions between "hot Jupiters" and their host stars can potentially enhance chromospheric and coronal activity. An ideal testbed for investigating this effect is provided by the extreme WASP-18 system, which features a massive (∼10 times Jupiter) close-in (0.94 day period) transiting planet orbiting a young F6 star. Optical and X-ray observations of WASP-18 were conducted in November 2011. The high-resolution echelle spectrograph MIKE was used on the 6.5m Magellan Clay telescope to obtain 13 spectra spanning planetary orbital phases of 0.7–1.4, while the X-ray Telescope on *Swift* provided contemporaneous monitoring with a stacked exposure of ∼50 ks. The cores of the Ca II H and K lines do not show significant variability over multiple orbits spanning ∼8 d, in contrast to the expectation of phase-dependent chromospheric activity enhancements for efficient star-planet interaction. The star is also X-ray faint, with $\log L_{\rm X} < 27.6$, indicating that coronal activity is likewise low. The lack of detectable star-planet interaction in this extreme system requires that any such effect must here be transient, if indeed present. We demonstrate that searches for Ca II H and K variability can potentially mistake a stellar hotspot, if observed over a short segment of the rotation period, for planet-induced activity. Taken together, these results suggest that the utility of star-planet interaction as a robust method of estimating exoplanet magnetic field strengths may be limited.

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Solar Abstracts

Solar Cycle Variation of Sound Speed Inside the Sun

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Empirical radial profiles of the changes in sound speed inside the Sun between solar minimum and solar maximum have been extracted from MDI data by Baldner & Basu (2008) and by Rabello-Soares (2012). Here, we compare these results with the theoretical radial profiles predicted by a model of magnetic inhibition of convective onset: in the model, the degree of magnetic inhibition is characterized by a parameter , which is essentially the ratio of magnetic pressure to gas pressure. We find that the theoretical profiles overlap significantly with the empirical results in the outer half of the convection zone. But differences in the deeper layers indicate that the model needs to be modified there. The main result which emerges in the present comparison is that the value of must be larger near the surface than at great depth. A secondary result is that, in the course of the solar cycle, the magnetic field magnitude at the base of the convection zone may be out of phase with the field near the surface.

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Effects of Hysteresis between Maximum CME Speed Index and Typical Solar Activity Indicators during Cycle 23

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Using the smoothed time series of maximum CME speed index data set for solar cycle 23, it is found that this index, analyzed jointly with six other solar activity indicators, show a hysteresis phenomenon. It is observed that total solar irradiance, coronal index, solar radio flux (10.7 cm), Mg II core-to-wing ratio, X-ray flare number and Hα flare index follow different paths for the ascending and the descending phases of solar cycle 23, while a saturation effect exists at the maximum phase of the cycle. However it is noticed that the separations between the paths are not the same for the different solar activity indicators used. Namely, Hα flare index and total solar irradiance depict broad loops while Mg II core-to-wing ratio and X-ray flare number depict narrow hysteresis loops. Lag times with respect to

the maximum CME speed index is discussed, confirming that hysteresis represents a clue in the search for physical processes responsible for changing solar emission.

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Occurrence of Extreme Solar Particle Events: Assessment from Historical Proxy Data

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The probability of occurrence of extreme solar particle events (SPEs) with the fluence of (> 30 MeV) protons $F_{30} \geq 10^{10}$ cm^{-2} is evaluated based on data of cosmogenic isotopes ^{14}C and ^{10}Be in terrestrial archives centennial-millennial time scales. Four potential candidates with $F_{30} = (1 \div 1.5) \cdot 10^{10}$ cm^{-2} and no events with $F_{30} > 2 \cdot 10^{10}$ cm^{-2} are identified since 1400 AD in the annually resolved ^{10}Be data. A strong SPE related to the Carrington flare of 1859 AD is not supported by the data. For the last 11400 years, 19 SPE candidates with $F_{30} = (1 \div 3) \cdot 10^{10}$ cm^{-2} are found and clearly no event with $F_{30} > 5 \cdot 10^{10}$ cm^{-2} (50-fold the SPE of 23-Feb-1956) occurring. This values serve as an observational upper limit for the strength of SPE on the time scale of tens of millennia. Two events, ca. 780 and 1460 AD, appear in different data series making them strong candidates to extreme SPEs. We built a distribution of the occurrence probability of extreme SPEs, providing a new strict observational constraint. Practical limits can be set as $F_{30} \approx 1$, 2÷3, and 5 10^{10} cm^{-2} for the occurrence probability $\approx 10^{-2}$, 10^{-3} and 10^{-4} year^{-1}, respectively. Because of uncertainties, our results should be interpreted as a conservative upper limit of the SPE occurrence near Earth. The mean SEP flux is evaluated as ≈ 40 (cm^2 sec)$^{-1}$ in agreement with estimates from the lunar rocks. On average, extreme SPEs contribute about 10% to the total SEP fluence.

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Solar Magnetic Flux Tube Simulations with Time-Dependent Ionization

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In the present work we expand the study of time-dependent ionization previously identified to be of pivotal importance for acoustic waves in solar magnetic flux tube simulations. We focus on longitudinal tube waves (LTW) known to be an important heating agent of solar magnetic regions. Our models also consider new results of wave energy generation as well as an updated determination of the mixing length of convection now identified as 1.8 scale heights in the upper solar convective layers. We present 1-D wave simulations for the solar chromosphere by studying tubes of different spreading as function of height aimed at representing tubes in environments of different magnetic filling factors. Multi-level radiative transfer has been applied to correctly represent the total chromospheric emission function. The effects of time-dependent ionization are significant in all models studied. They are most pronounced behind strong shocks and in low density regions, i.e., the middle and high chromosphere. Concerning our models of different tube spreading, we attained pronounced differences between the various types of models, which were largely initiated by different degrees of dilution of the wave energy flux as well as the density structure partially shaped by strong shocks, if existing. Models showing a quasi-steady rise of temperature with height are obtained via monochromatic waves akin to previous acoustic simulations. However, longitudinal flux tube waves are identified as insufficient to heat the solar transition region and corona in agreement with previous studies.

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ExoMol: Molecular Line Lists for Exoplanet and Other Atmospheres

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The discovery of extrasolar planets is one of the major scientific advances of the last two decades. Hundreds of planets have now been detected and astronomers are beginning to characterise their composition and physical characteristics. To do this requires a huge quantity of spectroscopic data most of which is not available from laboratory studies. The ExoMol project will offer a comprehensive solution to this problem by providing spectroscopic data on all the molecular transitions of importance in the atmospheres of exoplanets. These data will be widely applicable to other problems and will be used for studies on cool stars, brown dwarfs and circumstellar environments. This paper lays out the scientific foundations of this project and reviews previous work in this area.

A mixture of first principles and empirically-tuned quantum mechanical methods will be used to compute comprehensive and very large rotation-vibration and rotation-vibration-electronic (rovibronic) line lists. Methodologies will be developed for treating larger molecules such as methane and nitric acid. ExoMol will rely on these developments and the use of state-of-the-art computing.

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For preprints via ftp or WWW: www.exomol.com or arXiv:1204.0124

The Rovibrational Spectrum of BeH, MgH and CaH at High Temperatures in the $X\,^2\Sigma^+$ State: A Theoretical Study

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Accurate line lists for three molecules, BeH, MgH and CaH, in their ground electronic states are presented. These line lists are suitable for temperatures relevant to exoplanetary atmospheres and cool stars (up to 2000K). A combination of empirical and *ab initio* methods is used. The rovibrational energy levels of BeH, MgH and CaH are computed using the programs Level and DPotFit in conjunction with 'spectroscopic' potential energy curves (PECs). The PEC of BeH is taken from the literature, while the PECs of CaH and MgH are generated by fitting to the experimental transition energy levels. Both spin-rotation interactions (except for BeH, for which it is negligible) and non-adiabatic corrections are explicitly taken into account. Accurate line intensities are generated using newly computed *ab initio* dipole moment curves for each molecule using high levels of theory. Full line lists of rotation-vibration transitions for ^{9}BeH, ^{24}MgH, ^{25}MgH, ^{26}MgH and ^{40}CaH are made available in an electronic form as supplementary data to this article and at *url* www.exomol.com .

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Temperature-dependent Molecular Absorption Cross Sections for Exoplanets and Other Atmospheres

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Exoplanets, and in particular hot ones such as hot Jupiters, require a very significant quantities of molecular spectroscopic data to model radiative transport in their atmospheres or to interpret their spectra. This data is commonly provided in the form of very extensive transition line lists. The size of these line lists is such that constructing a single model may require the consideration of several billion lines. We present a procedure to simplify this process based on

the use of cross sections. Line lists for water, H_3^+, HCN /HNC and ammonia have been turned into cross sections on a fine enough grid to preserve their spectroscopic features. Cross sections are provided at a fixed range of temperatures and an interpolation procedure which can be used to generate cross sections at arbitrary temperatures is described. A web-based interface (www.exomol.com/xsec) has been developed to allow astronomers to download cross sections at specified temperatures and spectral resolution. Specific examples are presented for the key water molecule.

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Editor's Note: The abstracts below are being cross-listed with the *Star Formation Newsletter.*

Can We Predict the Global Magnetic Topology of a Pre-main Sequence Star From Its Position in the Hertzsprung-Russell Diagram?

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Zeeman-Doppler imaging studies have shown that the magnetic fields of T Tauri stars can be significantly more complex than a simple dipole and can vary markedly between sources. We collect and summarize the magnetic field topology information obtained to date and present Hertzsprung-Russell (HR) diagrams for the stars in the sample. Intriguingly, the large scale field topology of a given pre-main sequence (PMS) star is strongly dependent upon the stellar internal structure, with the strength of the dipole component of its multipolar magnetic field decaying rapidly with the development of a radiative core. Using the observational data as a basis, we argue that the general characteristics of the global magnetic field of a PMS star can be determined from its position in the HR diagram. Moving from hotter and more luminous to cooler and less luminous stars across the PMS of the HR diagram, we present evidence for four distinct magnetic topology regimes. Stars with large radiative cores, empirically estimated to be those with a core mass in excess of ∼40% of the stellar mass, host highly complex and dominantly non-axisymmetric magnetic fields, while those with smaller radiative cores host axisymmetric fields with field modes of higher order than the dipole dominant (typically, but not always, the octupole). Fully convective stars stars above $\sim 0.5\,M_\odot$ appear to host dominantly axisymmetric fields with strong (kilo-Gauss) dipole components. Based on similarities between the magnetic properties of PMS stars and main sequence M-dwarfs with similar internal structures, we speculate that a bistable dynamo process operates for lower mass stars ($< 0.5\,M_\odot$ at an age of a few Myr) and that they will be found to host a variety of magnetic field topologies. If the magnetic topology trends across the HR diagram are confirmed they may provide a new method of constraining PMS stellar evolution models.

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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.

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