COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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Stellar Abstracts

Mass Loss Rates from Coronal Mass Ejections: A Predictive Theoretical Model for Solar-Type Stars

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Coronal mass ejections (CMEs) are eruptive events that cause a solar-type star to shed mass and magnetic flux. CMEs tend to occur together with flares, radio storms, and bursts of energetic particles. On the Sun, CME-related mass loss is roughly an order of magnitude less intense than that of the background solar wind. However, on other types of stars, CMEs have been proposed to carry away much more mass and energy than the time-steady wind. Earlier papers have used observed correlations between solar CMEs and flare energies, in combination with stellar flare observations, to estimate stellar CME rates. This paper sidesteps flares and attempts to calibrate a more fundamental correlation between surface-averaged magnetic fluxes and CME properties. For the Sun, there exists a power-law relationship between the magnetic filling factor and the CME kinetic energy flux, and it is generalized for use on other stars. An example prediction of the time evolution of wind/CME mass-loss rates for a solar-mass star is given. A key result is that for ages younger than about 1 Gyr (i.e., activity levels only slightly higher than the present-day Sun), the CME mass loss exceeds that of the time-steady wind. At younger ages, CMEs carry 10–100 times more mass than the wind, and such high rates may be powerful enough to dispel circumstellar disks and affect the habitability of nearby planets. The cumulative CME mass lost by the young Sun may have been as much as 1% of a solar mass.

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For preprints via WWW: https://arXiv.org/abs/1704.06689

Detection of Starquakes on the Flare Star AD Leo

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The results of the analysis of the single color (B) observations undertaken at the Stefanion Observatory for the red dwarf star AD Leo at any stage of the stellar activity (quiescence, weak flares, strong flares), indicate that: (1) Transient high frequency oscillations occur during the flare event and during the quiet-star phase as well; (2) The observed frequencies range between 0.0005 Hz (period 33min) and 0.3 Hz (period 3s) not rigorously bounded. However, the quiescence parts of the light-curve which were analyzed belong to the pre- or after- flare state *i.e.* are connected with a major magnetic even (the observed flare). In this work we find that transient oscillations appear far apart from the observed flares, during the quiet state of the star, as a result of the general magnetic activity of the star. The power spectrum of these oscillations resembles those of the solar like oscillation spectra *i.e.* the sunquakes spectra. Finally, a tentative estimation of the main physical parameters of the star, using asteroseismic analysis, was performed.

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For preprints via WWW: https://doi.org/10.1002/asna.201713307 (to appear)

Metallicity Determination of M dwarfs. Expanded Parameter Range in Metallicity and Effective Temperature

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Reliable metallicity values for late K and M dwarfs are important for studies of the chemical evolution of the Galaxy and advancement of planet formation theory in low-mass environments. Historically it has been challenging to determine the stellar parameters of low-mass stars because of their low surface temperature, which causes several molecules to form in the photospheric layers. In our work we use the fact that infrared high-resolution spectrographs have opened up a new window for investigating M dwarfs. This enables us to use similar methods as for warmer solar-like stars. Metallicity determination with high-resolution spectra is more accurate than with low-resolution spectra, but it is rather time consuming. In this paper we expand our sample analyzed with this precise method both in metallicity and effective temperature to build a calibration sample for a future revised empirical calibration. Because of the relatively few molecular lines in the J band, continuum rectification is possible for high-resolution spectra, allowing the stellar parameters to be determined with greater accuracy than with optical spectra. We obtained high-resolution spectra with the CRIRES spectrograph at the Very Large Telescope (VLT). The metallicity was determined using synthetic spectral fitting of several atomic species. For M dwarfs that are cooler than 3575 K, the line strengths of FeH lines were used to determine the effective temperatures, while for warmer stars a photometric calibration was used. We analyzed 16 targets with a range of effective temperature from 3350-4550 K. The resulting metallicities lie between $-0.5 < [M/H] < +0.4$. A few targets have previously been analyzed using low-resolution spectra and we find a rather good agreement with our values. A comparison with available photometric calibrations shows varying agreement and the spread within all empirical calibrations is large. Including the targets from our previous paper, we analyzed 28 M dwarfs with high-resolution infrared spectra. The targets spread approximately one dex in metallicity and 1400 K in effective temperature. For individual M dwarfs we achieve uncertainties of 0.05 dex and 100 K on average.

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For preprints via WWW: https://arxiv.org/abs/1705.08785

Frequent Flaring in the TRAPPIST-1 System – Unsuited for Life?

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We analyze the K2 light curve of the TRAPPIST-1 system. The Fourier analysis of the data suggests $P_{\rm rot} = 3.295 \pm 0.003$ days. The light curve shows several flares, of which we analyzed 42 events with integrated flare energies of $1.26 \times 10^{30} - 1.24 \times 10^{33}$ ergs. Approximately 12% of the flares were complex, multi-peaked eruptions. The flaring and the possible rotational modulation shows no obvious correlation. The flaring activity of TRAPPIST-1 probably continuously alters the atmospheres of the orbiting exoplanets, making these less favorable for hosting life.

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An Updated 2017 Astrometric Solution for Betelgeuse

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We provide an update for the astrometric solution for the Type-II supernova progenitor Betelgeuse using the revised Hipparcos Intermediate Astrometric Data (HIAD) of van Leeuwen (2007), combined with existing VLA and new e-MERLIN and ALMA positions. The 2007 Hipparcos refined abscissa measurements required the addition of so-called Cosmic Noise of 2.4 mas to find an acceptable 5-parameter stochastic solution. We find that a measure of radio Cosmic Noise should also be included for the radio positions because surface inhomogeneities exist at a level significant enough to introduce additional intensity centroid uncertainty. Combining the 2007 HIAD with the proper motions based solely on the radio positions leads to a parallax of $\pi = 5.27 \pm 0.78$ mas (190^{+33}_{25} pc), smaller than the Hipparcos 2007 value of 6.56 ± 0.83 mas (152^{+22}_{17} pc; van Leeuwen 2007). Furthermore, combining the VLA and new e-MERLIN and ALMA radio positions with the 2007 HIAD, and including radio Cosmic Noise of 2.4 mas, leads to a nominal parallax solution of 4.51 ± 0.80 mas (222^{+48}_{34} pc), which while only 0.7σ different from the solution of Harper et al. (2008), is 2.6σ different from the solution of van Leeuwen. An accurate and precise parallax for Betelgeuse is always going to be difficult to obtain because it is small compared to the stellar angular diameter ($\theta = 44$ mas). An observing strategy utilizing future mm and sub-mm high spatial resolution interferometry is outlined that must be used if substantial improvements in precision and accuracy of the parallax and distance are to be achieved.

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The Inhomogeneous Sub-Millimeter Atmosphere of Betelgeuse

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The mechanisms responsible for heating the extended atmospheres of early-M spectral-type supergiants are poorly understood. So too is the subsequent role these mechanisms play in driving the large mass-loss rates of these stars. Here we present ALMA long (i.e., $\sim$16 km) baseline 338 GHz (0.89 mm) continuum obse rvations of the free-free emission in the extended atmosphere of the M2 spectral-type supergiant Betelgeuse. The spatial resolution of 14 mas exquisitely resolves the atmosphere, revealing it to have a mean temperature of 2760 K at $\sim 1.3\,\mathrm{R}_\star$, which is below both the photospheric effective temperature ($T_{\rm eff} = 3690\,\mathrm{K}$) and the temperatures at $\sim 2\,\mathrm{R}_\star$. This is unambiguous proof for the existence of an inversion of the mean temperature in the atmosphere of a red supergiant. The emission is clearly not spherically symmetric with two notable deviations from a uniform disk detected in both the im ages and visibilities. The most prominent asymmetry is located in the north-east quadrant of the disk and is spatially resolved showing it to be highly elongated with an axis-ratio of 2.4 and occupying $\sim$5% of the disk projected area. Its temperature is approximately 1000 K above the measured mean temperature at $1.3\,\mathrm{R}_\star$. The other main asymmetry is located on the disk limb almost due east of the disk center and occupies $\sim$3% of the disk projected area. Both emission asymmetries are clear evidence for localized heating taking place in the atmosphere of Betelgeuse. We suggest that the detected localized heating is related to magnetic activity generated by large-scale photospheric convection.

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Solar Abstracts

Updated Sunspot Group Number Reconstruction for 1749–1996 Using the Active Day Fraction Method

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Sunspot number series are composed from observations of hundreds of different observers that requires careful normalization of the observers to the standard conditions. Here we present a new normalized series of the number of sunspot groups for the period 1749–1996. The reconstruction is based on the active day fraction (ADF) method, which is slightly updated with respect to the previous works, and a revised database of sunspot group observations. Stability of some key solar observers has been evaluated against the composite series. The Royal Greenwich Observatory dataset appears fairly stable since the 1890s but is about 10% too low before that. A declining trend of 10–15% in the quality of Wolfer's observation is found between the 1880s and 1920s, suggesting that using him as the reference observer may lead to additional uncertainties. Wolf (small telescope) appears fairly stable between the 1860s and 1890s, without any obvious trend. The new reconstruction reflects the centennial variability of solar activity as evaluated using the singular spectrum analysis method. It depicts a highly significant feature of the Modern grand maximum of solar activity in the second half of the 20th century, being a factor 1.33–1.77 higher than during the 18–19th centuries. The new series of the sunspot group numbers with monthly and annual resolution, available also in the electronic format, is provided forming a basis for new studies of the solar variability and solar dynamo for the last 250 years.

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Weather on Other Worlds. IV. Hα Emission and Photometric Variability Are Not Correlated in L0–T8 Dwarfs

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Recent photometric studies have revealed that surface spots that produce flux variations are present on virtually all L and T dwarfs. Their likely magnetic or dusty nature has been a much-debated problem, the resolution to which has been hindered by paucity of diagnostic multi-wavelength observations. To test for a correlation between magnetic activity and photometric variability, we searched for Hα emission among eight L3–T2 ultra-cool dwarfs with extensive previous photometric monitoring, some of which are known to be variable at 3.6 μm or 4.5 μm. We detected Hα only in the non-variable T2 dwarf 2MASS J12545393−0122474. The remaining seven objects do not show Hα emission, even though six of them are known to vary photometrically. Combining our results with those for 86 other L and T dwarfs from the literature show that the detection rate of Hα emission is very high (94%) for spectral types between L0 and L3.5 and much smaller (20%) for spectral types $\geq$L4, while the detection rate of photometric variability is approximately constant (30%–55%) from L0 to T8 dwarfs. We conclude that chromospheric activity, as evidenced by Hα emission, and large-amplitude photometric variability are not correlated. Consequently, dust clouds are the dominant driver of the observed variability of ultra-cool dwarfs at spectral types at least as early as L0.

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Individual Dynamical Masses of Ultracool Dwarfs

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We present the full results of our decade-long astrometric monitoring programs targeting 31 ultracool binaries with component spectral types M7–T5. Joint analysis of resolved imaging from Keck and *HST* and unresolved astrometry from CFHT/WIRCam yields parallactic distances for all systems, robust orbit determinations for 23 systems, and photocenter orbits for 19 systems. As a result, we measure 38 precise individual masses spanning 30–115 $M_{\rm Jup}$. We determine a model-independent substellar boundary that is $\approx$70 $M_{\rm Jup}$ in mass ($\approx$L4 in spectral type), and we validate Baraffe et al. (2015) evolutionary model predictions for the lithium-depletion boundary (60 $M_{\rm Jup}$ at field ages). Assuming each binary is coeval, we test models of the substellar mass–luminosity relation and find in the L/T transition only Saumon & Marley (2008) "hybrid" models accounting for cloud clearing match our data. We derive a precise, mass-calibrated spectral type–effective temperature relation covering 1100–2800 K. Our masses enable a novel direct determination of the age distribution of field brown dwarfs spanning L4–T5 and 30–70 $M_{\rm Jup}$. We determine a median age of 1.3 Gyr, and our population synthesis modeling indicates our sample is consistent with a constant star formation history modulated by dynamical heating in the Galactic disk. We discover two triple brown dwarf systems, the first with directly measured masses and eccentricities. We examine the eccentricity distribution, carefully considering biases and completeness, and find that low-eccentricity orbits are significantly more common among ultracool binaries than solar-type binaries, possibly indicating the early influence of long-lived dissipative gas disks. Overall, this work represents a major advance in the empirical view of very low-mass stars and brown dwarfs.

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First Large Scale Herbig-Haro Jet Driven by a Proto-Brown Dwarf

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We report the discovery of a new Herbig-Haro jet, HH 1165, in SOAR narrow-band imaging of the vicinity of the σ Orionis cluster. HH 1165 shows a spectacular extended and collimated spatial structure, with a projected length of 0.26 pc, a bent **C**-shaped morphology, multiple knots, and fragmented bow-shocks at the apparent ends of the flow. The Hα image shows a bright halo with a clumpy distribution of material seen around the driving source, and curved reflection nebulosity tracing the outflow cavities. The driving source of HH 1165 is a Class I proto-brown dwarf, Mayrit 1701117 (M1701117), with a total (dust+gas) mass of $\sim$36 $M_{\rm Jup}$ and a bolometric luminosity of $\sim$0.1 $L_\odot$. High-resolution VLT/UVES spectra of M1701117 show a wealth of emission lines indicative of strong outflow and accretion activity.

SOAR/Goodman low-resolution spectra along the jet axis show an asymmetrical morphology for HH 1165. We find a puzzling picture wherein the north-west part exhibits a classical HH jet running into a pre-dominantly neutral medium, while the southern part resembles an externally irradiated jet. The **C**-shaped bending in HH 1165 may be produced by the combined effects from the massive stars in the ionization front to the east, the σ Orionis core to the west, and the close proximity to the B2-type star HR 1950. HH 1165 shows all of the signatures to be considered as a scaled-down version of parsec-length HH jets, and can be termed as the first sub-stellar analog of a protostellar HH jet system.

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Abstract Guidelines

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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.

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

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