COOLNEWS

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TABLE OF CONTENTS

Stellar Abstracts

The First Stellar Abundance Measurements in the Galactic Center: the M Supergiant IRS 7

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The first measurement of the photospheric abundances in a star at the Galactic Center are presented. A detailed abundance analysis of the Galactic Center M2 supergiant IRS 7 was carried out using high-resolution near-infrared echelle spectra. The Fe abundance for IRS 7 was found to be close to solar, [Fe/H] = -0.02 ± 0.13, and nearly identical to the Fe abundances we obtained for the nearby M supergiants α Ori and VV Cep. Analysis of the first and second overtone lines of CO was used to derive an effective temperature of 3600 ± 230 K, a microturbulent velocity of 3.0 ± 0.3 km s^{-1}, and a carbon abundance log ϵ(C) = 7.78 ± 0.13, or [C/H] = -0.77. In addition, we find a high depletion of 0.74 ± 0.32 dex in O and an enhancement of 0.92 ± 0.18 dex in N. These abundances are consistent with the dredge-up of CNO-cycle products but require deep mixing in excess of that predicted by standard models for red supergiants. In light of our measured solar Fe abundance for IRS 7, we discuss other indicators of metallicity at the Galactic Center, the interpretation of low-resolution near-infrared spectra of late-type giants and supergiants, including the need for caution in using such spectra as measures of metallicity, and the evolution of massive young stars at the Galactic Center. We suggest the possibility that rapid stellar rotation is common for stars formed under conditions in the Galactic Center, and that extra internal mixing induced by high rotation rates, rather than evolution at high metallicity, is the explanation for many of the unusual properties of the hot emission-line stars in the Galactic Center.

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ftp://ftp.astronomy.ohio-state.edu/pub/sellgren/carr_irs7.tar.gz

Starspot Photometry with Robotic Telescopes. UBV(RI)$_C$ and *by* Light Curves of 47 Active Stars in 1996/97

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We present continuous multicolor photometry for 47 stars from October 1996 through June 1997. Altogether, 7073 V(RI)$_c$, UBV, and *by* data points, each the average of three individual readings, were acquired with three automatic photoelectric telescopes (APTs) at Fairborn Observatory in southern Arizona. Most of our targets are chromospherically active single and binary stars of spectral type G to K but there are also four pre-main-sequence objects and three pulsating stars in our sample. The light variability is generally due to rotational modulation of an asymmetrically spotted stellar surface and therefore precise rotational periods and their seasonal variations are determined from Fourier analysis. We also report on photometric variations of γ CrB (A0V) with a period of 0.44534 days. All data are available in numerical form.

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Superflares on Ordinary Solar-Type Stars

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Short duration flares are well known to occur on cool main-sequence stars as well as on many tpes of 'exotic' stars. Ordinary main-sequence stars are usually pictured as being static on time scales of millions or billions of years. Our sun has occasional flares involving up to $\sim 10^{31}$ ergs which produce optical brightenings too small in amplitude to be detected in disk-integrated brightness. However, we identify nine cases of superflares involving 10^{33} to 10^{38} ergs on normal solar-type stars. That is, these stars are on or near the main-sequence, are of spectral class from F8 to G8, are single (or in very wide binaries), are not rapid rotators, and are not exceedingly young in age. This class of stars includes many of those recently discovered to have planets as well as our own Sun, and the consequences for any life on surrounding planets could be profound. For the case of the Sun, historical records suggest that no superflares have occurred in the last two millennia.

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ASCA X-ray Observations of the Super-metal-rich Stars 30 Ari and η Boo

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We present X-ray observations of two late-type stars, HR 764 (30 Ari B, F4V) and HR 5235 (η Boo, G0IV), with photospheric metal abundances about twice the solar value. We have derived the coronal temperatures and metallicities of these stars, and compared them with those of other stellar X-ray sources with solar or sub-solar photospheric composition, already observed with ROSAT and ASCA. The X-ray spectra of the two targets can be fitted with isothermal models yielding temperatures of 6.2 MK and 3.5 MK, and X-ray luminosities $\log L_{\rm x} = 29.6$ and 28.1 erg s^{-1}, for HR 764 and HR 5235 respectively. The best-fit model for HR 764, including a gaussian component which accounts for Fe XVII line emission from highly excited states, yields for its corona a solar (photospheric) iron abundance, while the best-fit iron abundance for HR 5235 is about half solar; however, in both cases, the uncertainties do not allow excluding values consistent with photospheric metallicities. Instead, the data indicate significant overabundances of

Mg and Si by factors 2–3 with respect to the Fe abundance, and suggest low O/Fe abundance ratios. We conclude that these two super-metal-rich stars appear to have coronal properties similar to those of other F and G main-sequence stars with "normal" photospheric abundances: in particular, HR 764 looks similar to the Hyades F stars, while the coronal temperature, luminosity and abundances of HR 5235 are similar to those of other field G dwarfs slightly younger than the Sun. The systematic pattern of O, Mg, Si, and Fe coronal abundances generally found for solar-type stars observed with ASCA is puzzling, because it does not appear related either to the photospheric composition or to the activity level.

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An Extreme X-ray Flare Observed on EV Lac by ASCA in July 1998

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We present a long (150 ks elapsed time) X-ray observation of the dM3.5e star EV Lac, performed with the ASCA observatory in July 1998, during which an exceptionally intense flaring event (lasting approximately 12 ks) was observed; at the flare's peak, the X-ray count rate in the ASCA GIS detectors was $\simeq 300$ times the quiescent value. The physical parameters of the flaring region have been derived by analyzing the decay, using both a "classic" quasi-static approach and an approach based on hydrodynamic simulations of decaying flaring loops. Notwithstanding the large peak X-ray luminosity, this second method shows that the flare's decay is compatible with its being produced in a relatively compact region of semi-length $L \simeq 1.3 \times 10^{10}$ cm ($\simeq 0.5\ R_*$), large but not exceptional even by solar standards. The flare decays is fast (with a measured e-folding time for the light curve of ≤ 2 ks), but nevertheless the hydrodynamic-based analysis shows strong evidence for sustained heating, with the shape of the light curve dominated by the time evolution of the heating rather than by the natural cooling of the flaring plasma. As a consequence, the quasi-static method yields a much larger estimate of the loop's length ($L \simeq 2\ R_*$). The event shows (similarly to some other well-studied large stellar flares) a light curve characterized by two separate decay time constants (with the initial decay being faster) and a significant enhancement in the plasma metal abundance at the peak of the flare. The energetics of the event are exceptional, with the peak X-ray luminosity of the event reaching up to $\simeq 25\%$ of the bolometric luminosity of the star, making this one of the largest X-ray flare (in relative terms) observed to date on a main-sequence star.

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Accurate Masses of Very Low Mass Stars: I Gl 570BC (0.6 $M_\odot$ +0.4 $M_\odot$)

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We present very accurate individual masses (1.2% relative accuracy) for the two components of Gl 570BC, an interferometric and double-lined spectroscopic binary system. They were obtained from new high accuracy radial velocity and angular separation measurements, analysed together with previously published measurements. From those data we determine a much improved orbit through a simultaneous least square fit to the radial velocity, visual, and parallax information. The derived masses and absolute magnitudes generally validate the theoretical and empirical mass-luminosity relations around 0.5 $M_\odot$, but point towards some low level discrepancies at the 0.1 to 0.15 magnitude level. Forthcoming results of this observing program will extend the comparison to much lower masses with similar accuracy.

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Two Nearby M Dwarf Binaries From 2MASS

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We report the discovery of two binary M dwarf systems in the immediate solar neighborhood using 2MASS. The first is an M6.5 companion to the nearby G star HD 86728 (Gl 376). The known properties of HD 86728 indicate that the M dwarf (Gl 376B) is old, metal-rich and only 14.9 parsecs away. The M dwarf is highly active with both Hα and X-ray emission. Thus, Gl 376B offers the opportunity to study an old, bright, active M dwarf with known metallicity, age, and luminosity. We show that it is probable that Gl 376B is itself an unresolved pair. The other system consists of an M6.5 and an M8 dwarf with 14.5 arcseconds separation. We estimate a distance of ~ 16 parsecs for this very low mass pair. Stronger activity is observed in the M6.5 dwarf, supporting evidence that chromospheric activity is weakening near the hydrogen burning limit.

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The Stellar Content of Soft X-ray Surveys II. Cross-correlation of the ROSAT All-Sky Survey with the Tycho and Hipparcos Catalogs

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We present the result of the cross-correlation of the ROSAT All-Sky Survey with the Tycho and Hipparcos catalogs. The constructed *RASS - Tycho* (RasTyc) and *RASS - Hipparcos* (RasHip) samples respectively consist of 13 875 and 6 200 matches and represent the largest and most comprehensive samples of stellar X-ray sources constructed so far. The X-ray horizon allows to probe distances up to about 200 pc for F - G RasTyc - RasHip stars younger than 100 Myr but only to 80 pc or less for older ones. The magnitude limit of the optical catalogs determine the horizon for K - M RasTyc - RasHip stars which are sampled only within about 50 pc (or less) of the Sun whatever their ages are. We compare the Hipparcos and RasHip HR-diagrams and discuss the differences. X-ray selection strengthens the Zero Age Main Sequence but evolved stars are detected as well. We compute detection rate, mean Fx/Fopt and X-ray luminosity with an unprecedented color bin resolution for *on* (between the Zero and Terminal Age Main Sequence i.e. class V) and *off* (above the Terminal Age Main Sequence i.e. class III) main sequence regions. Once corrected for Fx/Fopt bias, the detection rate is remarkably constant for G-M *on* main sequence stars but reveals a peak of detection for F-type stars. Detection rate in the A-type stars region is compatible with those computed for F-M stars, as expected if a late type companion is responsible for the X-ray emission. High mass stars evolving along the

post-main sequence evolutionary tracks are clearly detected in the main sequence turnoff and blue part of the "clump" while no significant detection arises on the cool side. Theoretical considerations naturally explain these observations. We address the question of the presence of very young stars in the solar neighborhood and derive an upper limit on the number of "possible" *isolated* pre-main sequence stars in the RasTyc-RasHip samples. Finally we discuss briefly the pending questions for which the RasTyc and RasHip samples are likely to give new insight.

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The Hot Side of the Lithium Dip – LiBeB Abundances Beyond the Main Sequence

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We extend to the case of A and early-F type stars our study of the transport of matter and angular momentum by wind-driven meridional circulation and shear turbulence. We show that our fully consistent treatment of the same hydrodynamical processes which can account for C and N anomalies in B type stars (Talon et al. 1997) and for the shape of the hot side of the Li dip in the open clusters (Talon & Charbonnel 1998) also explains LiBeB observations in stars with T_{eff} higher than 7000 K on the main sequence as well as in their evolved counterparts

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Four Nearby L Dwarfs

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We present spectroscopic, photometric and astrometric observations of four bright L dwarfs identified in the course of the 2MASS near-infrared survey. Our spectroscopic data extend to wavelengths shortward of 5000Å in the L0 dwarf 2MASSJ0746+2000 and the L4 dwarf 2MASSJ0036+1840, allowing the identification of absorption bands due to MgH and CaOH. The atomic resonance lines Ca I 4227Å and Na I 5890/5896Å are extremely strong, with the latter having an equivalent width of 240Å in the L4 dwarf. By spectral type L5, the D lines extend over $\sim$ 1000Å and absorb a substantial fraction of the flux emitted in the V band, with a corresponding effect on the (V-I) broadband colour. The KI resonance doublet at 7665/7699Å increases in equivalent width from spectral type M3 to M7, but decreases in strength from M7 to L0 before broadening substantially at later types. These variations are likely driven by dust formation in these cool atmospheres.

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Coronal Structure and Abundances of Capella from Simultaneous *EUVE* and *ASCA* Spectroscopy

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We report analysis of the simultaneous 1996 March *EUVE* and *ASCA* observations of the spectroscopic binary Capella. The *EUVE* spectrum is dominated by lines of highly ionized Fe, requiring a continuous emission measure distribution over a wide range of temperatures. The *ASCA* spectrum shows He-like line emission features of S, Si, and Mg, as well as unresolved L-shell emission lines of Fe and Ni and H- and He-like Ne lines. The flux in these line features cannot be determined independently from the continuum flux. The *ASCA* spectrum is relatively soft, with few counts above 4 keV.

The emission measure distribution determined by Line-Based Analysis of the EUV Fe line intensities is well constrained from $T_e \sim 6 \times 10^5$ to 2×10^7 K, but is not constrained above this range, since Fe XXIV is the highest temperature line observed with EUVE. Since repeated observations of Capella by *EUVE* have shown that emission line intensities of the hottest EUV-emitting material (Fe XXI to XXIV) vary by factors up to four, the *ASCA* spectrum is important for extending the temperature coverage. Thus the high energy cut-off of the *ASCA* spectrum provides a constraint on the highest temperature emission measures.

Elemental abundances are in principle determined from global fits to the *ASCA* spectrum; however, no well-fitting model has been found for the high signal-to-noise *ASCA* performance verification spectrum of Capella (1993 September 2). The newer *ASCA* spectrum of Capella (1996 March 3–4) shows a similar pattern of fitting difficulties. Using the *EUVE* measurements (1996 March 3–7) to constrain models, we have conducted sensitivity studies of the atomic data, source physics, and instrument calibration. The plasma spectral emission models (Raymond-Smith, MEKAL, SPEX) around 1.2 keV appear to have flux deficits relative to the observed *ASCA* count spectrum. New atomic models of Liedahl and Brickhouse, calculated with the HULLAC code, provide a set of lines — missing from the existing plasma codes — to fill in this flux deficit. Incorporating these additional lines dramatically improves the spectral model fits to the data, allowing reliable determination of elemental abundances. The successful application of the new atomic models to the Capella problem can have widespread implications, affecting spectral models of galaxies, cluster cooling flows, and supernova remnants, as well as other stellar coronae.

Analysis with the new atomic models of the simultaneous *ASCA* and *EUVE* data confirms the previous *EUVE* results that the continuous emission measure distribution of Capella has a strong enhancement at $T_e \sim 6 \times 10^6$ K. While a two-temperature model actually provides a better fit to the *ASCA* spectrum than the EUVE-derived continuous model, the *EUVE* data are not well fit with only two temperatures. We find that the abundances of Mg, Si, S, and Fe are consistent with solar photospheric values, while Ne appears to be under-abundant by a factor of $\sim$ 3 to 4.

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Velocity Variations of Semiregular Variables in the Infrared

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We obtained time series of high resolution spectra around 1.6 μm for 15 short period semiregular variables to study the velocity variations in their atmospheres with the help of second overtone vibration-rotational lines of CO. All objects of our sample clearly show velocity variations of a few km/s. The amplitude of the 'blue' SRVs (according to Kerschbaum & Hron 1992) is on the average a factor of two smaller than that of the 'red' SRVs. Periodicity of the variations differs from star to star. Some SRVs vary with the period listed in the General Catalogue of Variable Stars (GCVS4), others with a considerable longer period. But for all SRVs the measured velocities at 1.6 μm are over a large

part of the cycle smaller than the velocities found in the literature. Different explanations of this feature are discussed. We think that the observed difference in mean velocity might be caused by a blueshift due to large convective cells on the stellar surface.

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Solar Abstracts

Evidence for Non-Maxwellian Electron Energy Distributions in the Solar Transition Region: Si III Line Ratios from SUMER

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Recent calculations of Si III emission line strengths are compared with SUMER observations from a quiet solar region, a coronal hole and an active region. Diagnostic line ratios are used to derive T_e and N_e for the emitting plasma in each region, and good agreement between theory and observations is found. A major enhancement in the intensity of the 1313 Å emission line is observed, as well as some evidence of a small decrease in the temperature of maximum ionization fraction, as one moves from the coronal hole to the active region. Possible explanations for these effects are discussed, and it is concluded that they may be caused by the presence of non-thermal electrons in the transition region.

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Preconditioning the DEM(T_e) Inverse Problem

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In an inverse problem of any kind, poor conditioning of the inverse operator decreases the numerical stability of any unregularized solution in the presence of data noise. In this paper we show that the numerical stability of the differential emission measure (DEM) inverse problem can be considerably improved by judicious choice of the integral operator. Specifically, we formulate a combinatorial optimization problem where, in a preconditioning step, a subset of spectral lines is selected in such a way as to minimize explicitly the condition number of the discretized integral operator. We tackle this large combinatorial optimization problem using a genetic algorithm.

We apply this preconditioning technique to a synthetic dataset comprised of solar UV/EUV emission lines in the SOHO SUMER/CDS wavelength range. Following which we test the same hypothesis on lines observed by the Harvard S-055 EUV spectroheliometer. On performing the inversion we see that the temperature distribution in the emitting region of the solar atmosphere is recovered with considerably better stability and smaller error bars when our preconditioning technique is used, in both synthetic and "real" cases, even though this involves the analysis of *fewer* spectral lines than in the "All-lines" approach. The preconditioning step leads to regularized inversions that compare favorably to inversions by Singular Value Decomposition, while providing greater flexibility in the incorporation of physically and/or observationally-based constraints in the line selection process.

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Laboratory Spectroscopy of Hot Water Vapor in the $1.7 - 4.0\ \mu$m (2500 – 6000 cm^{-1}) Region: Application to Sunspots

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The infrared spectrum of a sunspot is analysed in the L-band region $4.0\ \mu$m (2497 – 3195 cm^{-1}) and $2.02 - 2.35\ \mu$m (4251 – 4962 cm^{-1}) in the K-band. A new laboratory emission spectrum covering 2500 – 6000 cm^{-1} is analysed to help make the assignments. Quantum number assignments are made using linelists computed using variational calculations, assisted by tabulations of experimental energy levels. 1207 new $H_2{}^{16}O$ lines are assigned in the L-band and 508 new lines in the K-band. Vibrational band origins of 11242.8 ± 0.1 cm^{-1} and 12586 ± 1 cm^{-1} are obtained for the (051) and (061) states.

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Observations of Sunspot Transition Region Oscillations

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Oscillations with a period of 3 minutes are observed in the transition region of six sunspots with the Solar and Heliospheric Observatory - SOHO joint observing programme for velocity fields in sunspot regions. Observations of the transition region lines O v λ629 and N v $\lambda\lambda$1238, 1242 with the SUMER instrument show significant differences in the amplitude of the 3 minute oscillations from one sunspot to another, both in intensity and line-of-sight velocity. In four sunspots the central part of the umbra is observed. Two of these sunspots show coincidence between the maxima in peak line intensity and velocity directed towards the observer, as is expected for an upward-propagating acoustic wave. The two other sunspots show large oscillation amplitudes and a difference of 25° between maxima in intensity and blueshift. The possible effect of partial wave reflection on the observed phase relation is discussed. For one sunspot only a part of the umbra, close to the penumbra, was observed and the observations show a difference of 50° between maxima in intensity and blueshift. For the smallest sunspot the observations are found to be contaminated by contributions from an area without oscillations. Observed oscillations in line width are small, but probably significant in two sunspots. The observations of NOAA 8378 allow us to compare simultaneous recordings of the oscillations in the chromospheric Si ii λ1260 line with the oscillations in the transition region lines. We question the suggestion by Fludra (1999) that the sunspot transition region oscillations are a typical feature of the sunspot plumes.

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Magnetic Energy Release in Flux Pile-up Merging

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The problem of pressure limitations on the rate of flux pile-up magnetic reconnection is studied. We first examine the recent suggestion of Jardine & Allen (1998) for moderating the build-up of magnetic pressure in the current sheet by considering inflows with nonzero vorticity. An analytic argument shows, however, that unbounded magnetic pressures in the limit of small resistivities can be avoided only at the cost of unphysical dynamic pressures in the plasma. Hence the pressure limitation on the reconnection rate in a low-beta plasma cannot be avoided completely. Nevertheless, we demonstrate that reconnection can be more rapid in a new solution that balances the build-up in dynamic pressure

against both the plasma and magnetic pressures. This exact MHD solution has the characteristics of merging driven by the coalescence instability. The maximum energy release rate of the model is capable of explaining a modest solar flare.

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Temporal Variability in the Electron Density at the Solar Transition Region

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The electron density as measured in the transition region of a coronal hole, a 'quiet' Sun region at disk center plus an active region shows variations of up to a factor of two at $T_e \sim 1.5\ 10^5 K$, lasting at most only a few minutes. There is remarkable agreement between the number of such variations, their temporal variability and duration in the coronal hole and 'quiet' Sun datasets, consistent with an earlier bright point study. There appears to be evidence of super-granular cells, with the increases in electron density occurring along the network boundaries. At some locations, periodicities of between 8 and 16 mins are visible in the electron density variations. We associate these variations with the sites of explosive events.

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Modelling Explosive Events in the Solar Atmosphere

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High–resolution ultraviolet (UV) spectra of the outer solar atmosphere show transient brightenings often referred to as explosive events. These are localized regions of small spatial extent that show sudden enhancements in the intensities of lines formed between 20,000 and 200,000 K, accompanied by strong non-gaussian profiles.

The present work is an attempt to extract observational consequences from computational simulations of the dynamic response of a coronal loop to energy perturbations. Explosive events are simulated in semi-circular magnetic flux tubes. Thermal energy perturbations drive flows along the flux tube giving rise to thermodynamic phenomena. The temporal evolution of the thermodynamic state of the loop is converted into C IV λ 1548.2 Å line profiles in (non)-equilibrium ionization. Time dependent carbon ion populations are obtained in the non-equilibrium conditions derived from the thermodynamic variables by means of an adaptive grid code. Most important, departures from ionization equilibrium are assessed for the first time under conditions such as those encountered in explosive events.

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