The University of Georgia
Department of Physics and Astronomy

Athens, Georgia 30602

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The following report covers the Department activities from October 1997 through October 1998.

1. PERSONNEL

Department members participating in astrophysics or astronomy research or instruction were Professors J. Scott Shaw and Jean-Pierre Caillault, Associate Professors Coates Johnson and Loris Magnani, Assistant Professor Peter Hauschildt, postdoctoral fellow Ian Short, graduate students Sangeeta Mysore, Inseok Song, Travis Barman, and Mariam Dittmann. Undergraduate students Laura E. Smith (UCLA) and Tony Ragona (Northeastern) spent the summer as NSF REU interns. In addition, University of Georgia undergraduates Katherine Davis and Hannah Curry spent the summer as NSF REU interns at Florida Tech and East Tennessee State, respectively, while Ben Engebreth and William Schomaker worked on summer research projects with Magnani and Hauschildt, respectively.

2. FACILITIES

The University of Georgia is a member of the Southeastern Association for Research in Astronomy (SARA), a consortium of five south-eastern universities (East Tennesse State, Valdosta State, Florida Tech, Florida International University and the University of Georgia). The consortium operates a 0.9-m telescope on Kitt Peak. This telescope is now completely functional with a CCD camera. Some remote observations have commenced and full robotic operation is expected in the winter of 1998/99. In addition, the consortium also operates a summer NSF REU program. The NSF has recently extended SARA's REU grant for 4 years.

The astronomy group at the University of Georgia has five SUN Sparcstations, two HP workstations, and numerous smaller machines available for data processing and computation. In addition, a 24-inch Cassegrain telescope is available on the roof of the Physics Building for teaching and public nights.

3. RESEARCH

Gagné (Rutgers), Caillault, Stauffer (CfA), and Linsky (JILA) have obtained *ASCA* observations of θ^1 Ori C. The only previous existing *ASCA* X-ray spectrum of the Trapezium region shows a very strong component of high temperature plasma, with emission measure approximately five times larger than that of the cooler component. Although *ASCA* cannot spatially resolve θ^1 Ori C from the remainder of the Trapezium, *ROSAT* HRI data can be used to limit the contribution of PMS stars to the overall flux. The observing program is designed to re-observe the Trapezium at θ^1 Ori C's rotational phases 0.0 and 0.5 in order to determine whether the spectrum changes as a function of rotational phase. This will allow them to distinguish between two scenarios for the X-ray emission of θ^1 Ori C: absorption of magnetospheric X-rays in a corotating wind or magnetosphere eclipses.

Mysore and Stauffer have obtained V- and I-band photometry of the moderately rich open cluster M35 (NGC2168). Since M35's age (70-100 Myr) is similar to that of the Pleiades cluster, a similar functional dependence on mass of the fraction of stars that appear to be photometrically variable is expected. However, a preliminary analysis shows M35 to be slightly older than the Pleiades as one begins to see large photometric variability of main sequence stars at only about spectral type K7, while the same occurs at about K2 in the Pleiades. Further analysis will allow for the determination of the fraction of fast rotators among the low-mass stars in M35. The observations were made from Nov. 1995 through Jan. 1996 at the Mt. Hopkins Observatory and the Kitt Peak National Observatory.

Song, Caillault, Stauffer, and Barrado (CfA) are attempting to determine the ages of Vega-type stars since this knowledge may play an important role in understanding whether planetary system formation is common. If the age determinations indicate that Vega-type stars are all very young, then this suggests that planet formation is common and that the range of dust optical depths is an age indicator; if the ages are spread out over a few hundred Myr, then planetary formation would be determined by random initial conditions. While it is difficult to determine directly the ages of individual A-stars, one can employ indirect methods, such as standard age-dating techniques for low-mass stars if the A-stars have such binary companions. Since young, low-mass stars are strong X-ray emitters, all of the archival ROSAT PSPC and HRI images which contain Vega-type candidates have been analyzed in order to determine whether there exist any X-ray sources within $\sim 10^4$ AU (roughly equivalent to $\sim 10'$) of the A-stars. Follow-up optical photometry and spectra of all possible optical counterparts have been obtained. Analyzing these data will determine whether the star is a physical companion to the A-star and, if so, both its age and that of the Vega-type candidate.

Shaw and Ragona have obtained a solution to the eclipsing binary RZ Draconis from UBVRI observations taken at Villanova University's 0.8 meter Automatic Photoelectric Telescope on Mt. Hopkins.

Shaw and Dittmann have completed observations of the open cluster NGC1342 at the SARA Observatory. The aim of the project is to find close binaries. Data are in the preliminary stages of reduction.

Magnani, D. Hartmann (CfA), and P. Thaddeus (CfA) continue to study the ''X-factor,'' the ratio of the molecular hydrogen column density to the velocity-integrated CO(J=1-0) antenna-temperature, in translucent molecular clouds. The current effort focusses on the variation of the X-factor from position to position in particular translucent clouds. The two clouds which have been studied thus far, MBM40 and MBM16, show markedly different behavior: The X-factor tends to vary significantly from position to position in MBM16 but not in MBM40. This variation may be due to the CO(1-0) integrated antenna temperature being a poor tracer of H_2 in low-column density regions.

Magnani, Hartmann, and Thaddeus have completed a survey for high-latitude molecular gas in the northern and southern Galactic hemisphere. The entire northern Galactic hemisphere has been sampled in a locally-cartesian 1 deg$\times$1 deg grid. A total of only 23 detections have been made in the North, underscoring the paucity of molecular gas at $b \geqslant 30°$. A similar survey of the Southern Galactic hemisphere has recently been completed and analysis is underway.

Hauschildt, Schwarz (Arizona State), Starrfield (Arizona State), Baron (Oklahoma), Allard (Lyon), and Shore (Indiana, South Bend) have calculated new detailed NLTE calculations for model atmospheres of novae during outburst. This fully self-consistent NLTE treatment for a number of model atoms includes 3922 NLTE levels and 47061 NLTE primary transitions. The new results show that the large set of NLTE lines constitute the majority of the total line blanketing opacity in nova atmospheres. Although LTE background lines are included, their effect is small on the model structures and on the synthetic spectra. The assumption of LTE leads to incorrect synthetic spectra and NLTE calculations are required for reliably modeling nova spectra. In addition, detailed NLTE treatment for a number of ionization stages of iron changes the results of previous calculations and improves the fit to observed nova spectra.

Hauschildt, Schwarz, Starrfield, Baron, Allard, Shore, and Whitelock (SAAO) modeled Nova LMC 1988 #1, a slow, CO type, dust-forming, classical nova. It was the first extragalactic nova to be observed with the IUE satellite. Ultraviolet and optical spectra of LMC 1988 #1 taken within the first two months of its outburst (when the atmosphere was still optically thick) were succesfully fit with synthetic spectra computed using PHOENIX nova model atmospheres. The synthetic spectra reproduce most of the features seen in the spectra and provide V band magnitudes consistent with the observed light curve. The fits are improved by increasing the CNO abundances to 10 times the solar values. The bolometric luminosity of LMC 1988 #1 was approximately constant at 2×10^{38} ergs s^{-1} at a distance of 47.3 kpc for the first 2 months of the outburst until the formation of the dust shell.

Hauschildt, Schwarz, Starrfield, Baron, Allard, Shore, and Sonneborn (GSFC) have analyzed the early optically thick ultraviolet spectra of Nova OS And 1986 using a grid of spherically symmetric, non-LTE, line-blanketed, expanding model atmospheres and synthetic spectra with the following set of parameters: $5{,}000 \leqslant T_{model} \leqslant 60{,}000$K, solar abundances, $\rho \propto r^{-3}$, $v_{max} = 2000$ km s^{-1},$L = 6 \times 10^4$ $L_\odot$, and a statistical or microturbulent velocity of 50 km s^{-1}. Synthetic spectra were used to estimate the model parameters corresponding to the observed *IUE* spectra. The fits to the observations were then iteratively improved by changing the parameters of the model atmospheres, in particular T_{model} and the abundances, to arrive at the best fits to the optically thick pseudo-continuum and the features found in the *IUE* spectra.

The *IUE* spectra show two different optically thick subphases. The earliest spectra, taken a few days after maximum optical light, show a pseudo-continuum created by overlapping absorption lines. The later observations, taken approximately 3 weeks after maximum light, show the simultaneous presence of allowed, semi-forbidden, and forbidden lines in the observed spectra. Analysis of these phases indicate that OS And 86 had solar metallicities except for Mg which showed evidence of being underabundant by as much as a factor of 10. A distance of 5.1 kpc to OS And 86 was obtained with a peak bolometric luminosity of $\sim 5 \times 10^4$ $L_\odot$. The computed nova parameters provide insights into the physics of the early outburst and explain the spectra seen by *IUE*. Lastly, evidence in the later observations for large non-LTE effects of Fe II are found which, when included, lead to much better agreement with the observations.

Hauschildt, Baron, and Allard, are working on the parallel implementation of the generalized stellar atmosphere and NLTE radiative transfer computer program PHOENIX. The implementation uses a MIMD design based on a relatively small number of MPI library calls. Parallel algorithms have been developed for radiative transfer, spectral line opacity, and NLTE opacity and rate calculations. These algorithms divided the work spatially or by spectral lines, i.e., distributing the radial zones, individual spectral lines, or characteristic rays among different processors. For finite, monotonic velocity fields, the radiative transfer equation is an initial value problem in wavelength, and hence each wavelength point depends upon the previous one. However, for sophisticated NLTE models of both static and moving atmospheres needed to accurately describe, e.g., novae and supernovae, the number of wavelength points is very large (200,000–300,000) and hence parallelization over wavelength can lead both to considerable speedup in calculation time and the ability to make use of the aggregate memory available on massively parallel supercomputers. A pipelined design for the wavelength parallelization of PHOENIX has been implemented, where the data from the processor working on a previous wavelength point is sent to the processor working on the succeeding wavelength point as soon as it is known.

Hauschildt, Audfenberg (Arizona State), Shore, and Baron successfully reproduce the full multi-wavelength spectrum, including the extreme ultraviolet (EUV) continuum observed by the *Extreme Ultraviolet Explorer*, of the B2 II star ϵ CMa with a non-LTE fully line-blanketed spherical model atmosphere. The available spectrophotometry of ϵ CMa from 350 Å to 25 μm is best fit with model parameters $T_{eff} = 21750$ K, $\log g = 3.2$, and an angular diameter of 0.77 mas. The model predicts a hydrogen ionizing flux, q_0, of 1.59×10^{21} photons cm^{-2} s^{-1} at the star's surface and 5540 photons cm^{-2} s^{-1} at the surface of the Local Cloud. The synthetic spectra are in excellent agreement with observed continuum and line fluxes from échelle spectra obtained with the Goddard High Resolution Spectrograph. While agreement between the absolute UV flux of ϵ CMa as measured by *GHRS* and the model atmosphere is found, these fluxes are $\sim$ 30% higher in the UV than measured by *IUE*, *OAO-2*, and *TD-1*, in excess of the published errors in the absolute calibration of these data. The *IUE* and *TD-1* data appear to have a wavelength independent systematic error in their absolute calibration of 30%. The *OAO-2* data, in agreement with the model's absolute flux between 1200 Å and 2000 Å, lie 30% below the model and *GHRS* fluxes from 2000 Å to 3000 Å, suggesting a relative as well as absolute calibration error in these data.

The agreement between the model and the measured EUV flux is a result of the higher temperatures at the formation depths of the H I and He I Lyman continua compared to other models. These higher temperatures increase the level of the EUV continuum and reduce the strength of the 912 Å and 504 Å edges. An important difference between these calculations and previous calculations is the computation of the model atmosphere out to very small optical depths which results in higher temperatures in the EUV continuum forming region.

Hauschildt, Baron, Nugent (LLNL) and Branch (Oklahoma) have modeled supernovae near maximum light. These objects, with their diversity of compositions, velocities, envelope masses, and interactions are good testing grounds for probing the importance of NLTE in expanding atmospheres. In addition to treating H, He, Li I, O I, Ne I, Na I, and Mg II in NLTE, a very large model atom of Fe II is used to test the importance of NLTE processes in both SNe Ia and II. Since the total number of potential line transitions that one has to include is enormous ($\sim$ 40 million), approximations and simplifications are required to treat the problem accurately and in finite computer time. With a large Fe II model atom (617 levels, 13,675 primary NLTE line transitions) several assumptions for treating the background opacity that are needed to obtain correct UV line blanketing which determines the shape of near-maximum light supernova spectra can be tested. Due to interactions within the multiplets, treating the background lines as pure scattering (thermalization parameter $\epsilon = 0$) is found to be a poor approximation and that an overall mean value of $\epsilon \sim 0.05 - 0.10$ is a far better approximation. This is true even in SNe Ia, where the continuum absorption optical depth at 5000 Å ($\equiv \tau_{\rm std}$) is $\ll 1$. A detailed treatment of NLTE effects is required to properly determine the ionization states of both abundant and trace elements.

Hauschildt, with Allard, Alexander (Wichita State), and Starrfield are modeling the atmospheres of very low mass stars and brown dwarfs. As progressively cooler stellar and substellar objects are being discovered, the presence of first molecules and then condensed particulates greatly complicates the understanding of their physical properties. Accurate model atmospheres which include these processes are the key to establishing their atmospheric parameters. They play a crucial role in determining structural characteristics by setting the surface conditions of model interiors, and by providing transformations to the various observational planes. In addition, they can reveal the spectroscopic properties of brown dwarfs and help establish their detectability. This project incorporates molecular and grain opacities in cool stellar spectra, as well as the latest progress in (i) deriving the effective temperature scale of M dwarfs, (ii) reproducing the lower main sequences of metal-poor subdwarfs in the halo and globular clusters, and (iii) interesting results of the models related to the search for brown dwarfs.

Hauschildt, Baraffe (Lyon), Chabrier (Lyon), and Allard present new evolutionary calculations for low-mass and very low-mass M-dwarfs, for a metallicity range $-2 \leqslant [M/H] \leqslant 0$, down to the hydrogen-burning minimum mass ($0.07 < M/M_\odot < 0.6$). The calculations include the best input physics presently available, i.e., equation of state, enhancement of nuclear reaction rates and atmosphere models. The most recent atmospheric model based on synthetic spectra at finite metallicity, and grey atmosphere models based on Alexander and Ferguson (1994) Rosseland opacities are used. Comparisons are made with observational results down to the bottom of the main sequence, for different metallicities, in a magnitude (M_V) - color ($V - I$) diagram, and in color-color I,J,H,K diagrams. Excellent agreement is found between theory and observations over the whole characteristic temperature/luminosity range. This enables the determination of the mass of the faintest objects observed, which is found to be $m_{lim} \approx 0.085\,M_\odot$ for [M/H]=0 and -0.5, and $m_{lim} = 0.09\ M_\odot$ for [M/H]=-1.5, for an age of 10 Gyrs.

Hauschildt, Allard, Jones, and Viti (UCL) compare observations of the binary system CM Draconis with synthetic spectra computed using the stellar atmosphere code PHOENIX. Spectroscopic observations from 0.40 to 2.41μm, combined with photometry and the accurately known surface gravity allow an estimate of the temperature and metallicity using detailed spectral synthesis. Discrepancies between the analysis of the infrared and optical spectrum are found: while the optical spectral energy distribution (SED) yields a metal-rich solution with $T_{\rm eff}$=3000 K, the infrared SED yields $-0.8 \leqslant [M/H] \leqslant -0.6$, compatible with the high space motion of the system. The low-metallicity characteristics of the infrared SED could be real and is partly supported by a detailed analysis of the atomic lines in the optical region. However, the known incompleteness of the TiO and H_2O line lists in the models used as well as problems with the observational data will cause systematic errors.

Hauschildt, Allard, Alexander, Schweitzer (LSW-Heidelberg), and Baron are modeling the atmospheres for M dwarfs and giants. The atmospheres of M stars are dominated by a small number of very strong molecular compounds (H_2O, TiO, H_2, CO, VO). Most of the hydrogen is locked in molecular H_2, most of the carbon in CO; and H_2O, TiO and VO opacities define a pseudo-continuum covering the entire flux distribution of these stars. The optical ''continuum'' is due to TiO vibrational bands which are often used as temperature indicators for these stars. These may be the depth of the bands relative to the troughs in between them; or the depth of the VO bands; or of the atomic lines relative to the local ''continuum''; or even the strength of the infrared water bands. All of these depend on the strength of the TiO bands and the amount of flux-redistribution to longer wavelengths exerted by them. Departures from LTE of the Ti I atom, and thus the concentration of the important TiO molecule, could, therefore, have severe and measurable consequences on the atmospheric structure and spectra of these stars. Due to the very low electron temperatures, the electron density is extremely low in M stars; even lower than in novae and SNe. Collisions with particles other than electrons, e.g., H_2 or helium, are by far not as effective as electron collisions, both because of their smaller cross-sections and their much smaller relative velocities. Therefore, collisional rates which tend to restore LTE, could be very small in cool stars. This, in turn, could significantly increase the importance of NLTE effects in M stars when compared to, e.g., solar type stars.

Hauschildt, Aufenberg, Sankrit (Arizona State), and Baron successfully reproduce the full multi-wavelength spectrum, including the extreme ultraviolet (EUV) continuum observed by *Extreme Ultraviolet Explorer*, of the B1 II-III star β CM with a non-LTE fully line-blanketed spherical model atmosphere. The available spectrophotometry of β CMa from 500 Å to 25 μm and Balmer lines Hγ and Hδ are best fit with model parameters T_{eff}=24000 K, log g= 3.4, and an angular diameter of 0.57 mas. Together with the *HIPPARCOS* distance these results provide fundamental stellar parameters for β CMa. A neutral interstellar hydrogen column of $N(HI) = 2 \times 10^{18}$ cm^{-2} provides the best agreement between the model EUV flux and that observed by *EUVE*. In addition, a very diffuse HII region surrounding β CMa is leaking 0.5% of its ionizing flux into the surrounding interstellar medium.

As a check, a model is computed for the primary of the resolved spectroscopic binary α Vir for which independently determined values for the mass and radius are available. For α Vir , parameters $T_{eff} =$ 23070 K, log $g = 3.6$, and angular diameter = 0.93 mas provide the best match to the UV, optical, and IR spectrophotometry and the Balmer line profiles. The mass and radius of α Vir derived from the model fit and *HIPPARCOS* distance are in agreement with values from direct measurements. The model for α Vir predicts 1.6 times more hydrogen ionizing flux than previous models. However, this falls short of the measured lower limit from an Hα mapping of the HII region around α Vir.

Hauschildt, Pistinner (Bar Sheba), Eichler (Bar Sheba), and Baron calculate a grid of spherically symmetric OB stellar atmospheres at low metallicities, including both non-local thermodynamic equilibrium-(NLTE) and metal line blanketing effects. This is done to assess the uncertainties in helium abundance determination by nebular codes due to input stellar atmosphere models. The more sophisticated stellar atmosphere models which are used can differ from LTE models by as much as 40 percent in the ratio of He- to H-ionizing photons.

Hauschildt, Leggett (Hawaii), and Allard present new infrared JHK photometry for 61 halo and disk stars around the stellar/substellar boundary. In addition, new L' photometry for 21 of these stars and for 40 low–mass stars taken from the Leggett 1992 photometry database is compiled. These data are combined with available optical photometry and astrometric data to produce color–color and absolute magnitude–color diagrams. The current sample extends work presented earlier into more metal–poor and lower mass regimes. The disk and halo sequences are compared to the predictions of the latest model atmospheres and structural models. Good agreement is found between observation and theory except for known problems in the V and H passbands probably due to incomplete molecular data for TiO, metal hydrides and H_2O. The metal–poor M subdwarfs are well matched by the models as oxide opacity sources are less important in this case. The known extreme M subdwarfs have metallicities about one–hundredth solar, and the coolest subdwarfs have $T_{eff} \sim 3000$ K with masses $\sim 0.09 M/M_{\odot}$. The grainless models are not able to reproduce the flux distributions of disk objects with $T_{eff} <$ 2500 K, however a preliminary version of the NextGen–Dusty models which includes homogeneous formation and extinction by dust grains is able to match the colors of these very cool objects. The least luminous objects in this sample are GD165B, three DENIS objects — DBD0205, DBD1058 and DBD1228 — and Kelu-1. These have $T_{eff} \sim$ 2000 K and are at or below the stellar limit with masses $\leqslant 0.075 M/M_{\odot}$. Photometry alone cannot constrain these parameters further as the age is unknown, but published lithium detections for two of these objects (Kelu-1 and DBD1228) imply that they are young (aged about 1 Gyr) and substellar (mass $\leqslant 0.06 M/M_{\odot}$).

Hauschildt, Shahbaz (Oxford), and Taylor (Oxford) have obtained high resolution echelle spectroscopy of the recurrent nova T CrB. The surface abundance of Li in T CrB is compared with field M-stars and is found to be somewhat below solar, whereas in the M3*III* field stars it is nonexistent. Possible explanations for this include either a delay in the onset of convection in the giant star, enhanced coronal activity due to star-spots or the enhancement of Li resulting from the nova explosion.

Hauschildt and Baron discuss numerical methods and algorithms for the solution of NLTE stellar atmosphere problems involving expanding atmospheres, e.g., found in novae, supernovae and stellar winds. A scheme of nested iterations can be used to reduce the high dimension of the problem to a number of problems with smaller dimensions. As examples of these sub-problems, the numerical solution of the radiative transfer equation for relativistically expanding media with spherical symmetry is analyzed along with the solution of the multi-level non-LTE statistical equilibrium problem for extremely large model atoms, and the temperature correction procedure.

Hauschildt, Ciardi (Wyoming), and Howell (Wyoming) present phase–resolved near–infrared broadband photometry of four short period cataclysmic variables (HU Aqr, WZ Sge, TY Psc, & V592 Cas). Coupled with ultraviolet and optical data obtained from the literature, the spectral energy distributions of these four cataclysmic variables are modeled, as well as the twin of WZ Sge, AL Com. The secondary stars contribute no more than 20–50% of the near–infrared flux except for the polar HU Aqr where the secondary contributes $\sim$ 75% of the near–infrared flux. For the systems located above the orbital period minimum, the temperatures of the secondary stars match those for the expected main sequence secondary stars. However, the modeling places WZ Sge below the orbital period minimum and containing a secondary star of $<$ 1700 K – the coldest star yet identified.

Hauschildt, Ciardi, Howell, Dhillon (Oxford), Wagner (KPNO), and Allard present near–infrared and optical spectroscopic observations of the polar ST Leonis Minoris (ST LMi) in an extreme low–state. The near–infrared spectrum, showing no emission lines whatsoever, is produced solely by the secondary star. The spectrum with a series of stellar atmosphere models is fit and the secondary star is found to have a temperature of 2800± 200 K. Six months later, ST LMi was reobserved in the near–infrared, at which time mass transfer had resumed, and the system was now in a high state. Evidence suggests that the second pole in ST LMi was actively accreting material.

Hauschildt, Allard, and Baron present a NextGen Model Atmosphere grid for low mass stars to effective temperatures larger than 3000 K. These LTE models are calculated with the same basic model assumptions and input physics as the VLMS part of the NextGen grid so that the complete grid can be used, e.g., for consistent stellar evolution calculations and for internally consistent analysis of cool star spectra. This grid is also the starting point for a large grid of detailed NLTE model atmospheres for dwarfs and giants. The models were calculated from 3000 K to 10000 K (in steps of 200 K) for $3.5 \leqslant \log g \leqslant 5.5$ (in steps of 0.5) and metallicities in the range from -4.0 to 0.0.

Short and Hauschildt have incorporated into the PHOENIX model atmosphere code the ability to treat Fe, Ni, and Co up to ionization stage VI, Mg, Ca, and Al up to ionization stage III, and S and Si up to ionization stage IV, *out* of local thermodynamic equilibrium (LTE) using a multi-level direct method with large model atoms (≈ 400 levels and ≈ 7500 transitions in the case of Ni III). These species are critically important for modeling the time development of Novae spectra. The ability to treat similarly Cs, Rb, and K, which are important for fitting chromospheric models to M dwarf spectra has been added, in addition to Ba which is important for modeling SNe supernovae. This is an increase from 40 to 85 in the total number of ionization stages among all species treated in non-LTE by PHOENIX, and provides an unprecedented ability to directly compute multi-species, multi-level non-LTE solutions with a model atmosphere code. The equation of state, and the chemical, thermal, and hydrostatic equilibrium equations are all solved consistently with the non-LTE equilibrium of all the species treated in non-LTE. Also, the addition of many new non-LTE species allows computation of synthetic spectra with self-consistent, massive non-LTE line blanketing due to many more atoms and ions than has previously been possible.

Short, Byrne (Armagh), and Panagi (Redding) present the first simultaneous multi-line fitting of a semi-empirical atmospheric model with a chromosphere and transition region to the H I and Ca II spectra of an RS Can Ven star (II Peg). The static component of the Hα emission core, the line profile of Hβ, the apparent absence of Hγ and Hδ, and the emission core profiles of Ca II K and two of the Ca II IR^3 lines are all approximately fit by a static 1D model with the following properties: $\log m$ at the onset of the transition region is ≈ -2.85, and a 6000 K plateau in the upper chromosphere that spans about a decade in $\log m$. In particular, the model is able to reproduce the unusually steep Balmer decrement (compared to the dMe stars), in which Hα is strongly in emission and Hβ is in absorption, without recourse to extra-atmospheric material. This latter result is found to hold when the metal abundance is varied in the background opacity calculation of the non-LTE H I calculation. The Ca II IR^3 lines are best fit by a model in which $T_{\rm min}$ is cooler by 300 K and shallower by over half a decade in $\log m$ than that which best fits the optical lines. The emergent flux in the IR^3 line cores arises from the $T_{\rm min}$ region, whereas the flux the other diagnostics arises from layers well above $T_{\rm min}$, and it is postulated that this may be the cause of the discrepancy.

Short and Doyle (Armagh) have obtained simultaneous high resolution Hα and Na I D spectra of five dwarf M stars that span a wide range in chromospheric activity level. The observed Na I D lines exhibit behavior that is qualitatively similar to that of more well established diagnostics such as the Ca II HK lines: as the activity level, as indicated by the Hα line, increases, the absorption core brightens and then develops an emission reversal. The observed profiles are compared with computed non-LTE profiles from a grid of chromospheric/transition region models. The Hα and Na I D lines tend to be in general agreement as indicators of approximate chromospheric activity level. However, the Hα line systematically indicates a value for the mass loading at the onset of the Transition Region and the location of $T_{\rm min}$ that is 0.3 dex lower in column mass density than that indicated by Na I D. Therefore, the profile of both lines cannot be simultaneously well fit for all but one of our stars. For dMe stars the shape of the Na I D emission cores is a much more sensitive indicator of chromospheric thickness (or, equivalently, chromospheric steepness) than is Hα, and, therefore, provides a powerful diagnostic complement to Hα. Finally, the dependence of the predicted line profiles on the values of the stellar parameters is investigated and it is found that the inferred chromospheric pressure is sensitive to the choice of $T_{\rm eff}$ and $\log g$, especially among dMe stars.

Short and Doyle have obtained, for the first time, a high resolution near-infrared spectrum in the region of Paβ of a chromospherically active M dwarf (AU Mic). They demonstrate that both Paβ and Hα can be fit with a model of large chromospheric pressure, but that the two lines indicate clearly different values of the exact pressure. There are several important types of missing physics that need to be included in the calculations before the importance of this apparent discrepancy can be assessed. Nevertheless, the approximate agreement of the two lines lends support to an earlier theoretical result that the Paschen series is a useful chromospheric diagnostic in M dwarfs.

Doyle, Short, Byrne, and Amado (Catania) failed to detect the nearby faint M dwarf star Gl 105B (a star of anomalously low chromospheric and coronal activity) with the HRI onboard ROSAT, implying $\log L_x < 26.1$. High resolution optical data for Ca II HK indicate a surface flux of $\approx 6.5 \times 10^3$ erg cm^{-2} s^{-1}, in good agreement with the previously measured Mg II hk flux. Based on chromospheric modeling both the Hα and Ca II K line profiles indicate an atmospheric structure which is intermediate between that of an intermediate dM chromosphere and a basal chromosphere. Also, the modeling indicates that a better fit is obtained using a model atmosphere which has T_{min} less than 2650 K, and a thin steep chromosphere. Furthermore, the Ca II HK radiative losses may only be ≈ 5% of the radiative losses in the UV continuum, implying total chromospheric losses in excess of 10^5 erg cm^{-2} s^{-1}.

PUBLICATIONS

The publication list includes all papers published or submitted between October 1997 and October 1998 by the staff.

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