Summary of the Twelfth Cool Stars Workshop: Insights, Mysteries, and Action Items

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Abstract.
This paper summarizes the Twelfth Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun held in Boulder, Colorado on July 30 to August 3, 2001. I describe many of the important new results and insights presented at the meeting and list the important unanswered questions that should drive future research in the field. Finally, I present a set of urgent action items that are needed if we are to maintain and enhance research opportunities in the field.

"Much more is known than is actually true." *J. R. Pierce*

"It ain't necessarily so." *George and Ira Gershwin*

1. Introduction

We are approaching the end of another absolutely stimulating workshop in which the latest studies of late-type stars and the Sun have been presented and debated from both observational and theoretical perspectives. Cool Stars 12 has covered a broad territory, including stars with luminosities from supergiants to dwarfs and even to planets, observations from the radio to X-rays, stellar ages from class 0 protostars to highly evolved stars, and stellar structure from the deep interior to the interface of the stellar wind with the ISM. Since the last meeting in Tenerife, our field has been stimulated by the first stellar X-ray spectra and very high resolution X-ray images of young star forming regions obtained with the Chandra and XMM-Newton observatories, and by observations from sensitive new ground-based instruments operating in the optical and infrared.

Given the wealth of new observations and theory, it is difficult to decide where to begin. I will start by thanking the Scientific Organizing Committee and the Local Organizing Committee for creating Cool Stars 12 in this pleasant environment where science and the beautiful outdoors meet. Many of us will remember our hikes into the Indian Peaks Wilderness or in the nearby mountains as one of the highlights of the meeting. A new format at this meeting is the topical session with a coordinator who introduces the topic and provides the context for the contributed papers. I believe that this innovation has been a great success largely because the session coordinators have performed their difficult tasks beautifully. They deserve our sincere thanks.

A strong impetus for this series of workshops has been to explore the solar-stellar connection to determine which types of stars show phenomena similar to the Sun and which types of stars do not. By studying how these phenomena depend on stellar properties (e.g., mass, age, gravity, metal abundance, rotation rate, binarity, magnetic field strength), we can test physical models that have been put forward to explain the phenomena. Many speakers and posters have addressed this vital question. Since pre-main sequence (PMS) stars clearly exhibit phenomena very different from the Sun, largely due to the importance of accretion and interactions with disks, the solar-stellar disconnection is now becoming a major theme of these meetings. Just how a PMS star evolves to become an inactive sun-like star was a very lively topic at this meeting that we need to continue addressing in the future.

Three themes immediately come to mind when I think about this meeting. First, the recognition of the importance of the H_2 molecule. We are finding emission lines of H_2 in the Sun (especially in spots), K and M giants and supergiants, L- and T-dwarfs, Mira B, and especially PMS stars. These lines are seen in the infrared from the ground and by ISO, in the ultraviolet by HST/STIS, and now in the far-ultraviolet by FUSE. The UV lines are mostly pumped by Ly-α but also by C II 1335 Å, Si IV 1393 Å, C IV, N III, even O VI (for the Werner band). A second theme is the importance of panchromatic observations of the same phenomena across the electromagnetic spectrum with simultaneous observations even more valuable. Bringing together X-ray, UV, optical, IR, and radio data is often essential to understand the physics responsible for complex phenomena like stellar flares. A third theme is the strong emphasis on the physical processes that could explain the phenomena.

2. New Insights

Here is my list of the most interesting developments presented at the meeting. This list is not complete because I could not see all of the posters or attend the parallel session on brown dwarfs and planets:

Extrapolating from the Sun: One of the highlights of the meeting was the series of computer models created by Schrijver showing the behavior of a hypothetical active star with properties identical to the Sun but with rates of magnetic flux emergence into the photosphere up to 30 times larger than for the Sun. The computed magnetic field structure for this very active star has many properties that are very different from the Sun:

- A polar crown with one magnetic polarity (300–400 G). This "confirms" the reality of polar spots, previously discovered by photometry and Doppler imaging of active stars, if we follow Eddington's advice that observations are not to be trusted until confirmed by theory.
- A surrounding ring of opposite polarity also seen by Hussein in Zeeman Doppler images of AB Dor.
- A global magnetic field that Feigelson suggests may be typical for PMS stars.
- The computed linear dependence of X-ray surface flux on $< fB >$ similar to what Saar (1996) has observed.

These computer simulations may provide a partial answer to Walter's question about the evolution of PMS stars, "I don't know how we get from here to the Sun."

Differential Rotation: Reiners presented the first measurements of stellar differential rotation. The F5 V star ψ Cap has differential rotation with the same magnitude and sign as the Sun! This provides guidance to theoreticians who want to model the interior structure and dynamo properties of stars different from the Sun using the kinematic solar models obtained from helioseismology.

Convective Cells: For many years we have assumed, based on Schwarzschild's (1975) theoretical arguments, that supergiant stars like Betelgeuse have a very small number of large convective cells in their photospheres. Gray presented a contrary view. He argued that the absence of discrete components in the absorption lines of Betelgeuse indicates that roughly 600 convective cells are present in the photosphere at one time rather than just a few. Advances in high resolution imaging are needed to determine which viewpoint is correct.

The Solar-Stellar Nonconnection: Walter began his introduction to the session on early stellar evolution by saying "Let's start by demolishing the solar analogy." The Sun provides a good role model for stars when the sources of energy to the photosphere and above are qualitatively the same, although the heating rates may be orders of magnitude larger than for the Sun. PMS stars are fundamentally different from the Sun because accretion and interactions with the gas and magnetic fields in the disk are important energy sources not present in the Sun. This likely explains the very different phenomenology of PMS stars, and why previous attempts to understand PMS stars by extrapolating solar models of flares and X-ray emission to much higher input energies did not work.

Testing the Solar-Stellar Connection: We heard a lot at the meeting, especially during the early evolution section on Monday, about situations in which the solar-stellar connection doesn't seem to work. Nevertheless, there are roughly 10^{12} middle-aged late-type dwarf stars in our Galaxy, which arguably are solar-like and for which our cherished solar-stellar connection principal should apply. In comparing these solar-like stars to our own Sun, we are faced, however, with the quandary that has plagued our field ever since its inception some three decades ago; namely, the extreme brightness of the Sun prevents it from being observed by the same instruments and in the same way as for the distant, dim stars. There is, for example, the long-standing controversy over the solar $B-V$ color. At CS12, we saw other examples. Consider the heated debate between Stern and Ayres concerning the variation of the solar X-ray flux over the sunspot cycle as seen in the *ROSAT* 0.2-2.0 keV band: Historically, long-term solar X-ray monitoring (by *Yohkoh* or the GOES instruments) has been at higher energies that are difficult to trace back to the equivalent soft PSPC band. Also, Pagano and Curdt compared solar far-UV spectra to a beautiful STIS spectrum of the solar-twin α Cen A. The comparison suffered because the SUMER solar spectra are for specific positions on the resolved solar disk, whereas the STIS spectra are for the star as a point source, and because of the $\sim 8\times$ lower spectral resolution of SUMER versus the high-resolution of the STIS echelle mode. Further progress in the solar-stellar connection would benefit greatly from the ability to observe the Sun as a star using the same type of instrumental capabilities that routinely are applied on the stellar side. We should encourage solar instrumentalists to include "sun as a star" modes in their new experiments, even as nighttime astronomers strive someday to directly image surface features on other stars.

H_2 Fluorescence: We now know that H_2 emission and absorption lines appear in a wide variety of stellar spectra, and we have some insight into their formation.

- H_2 emission lines appear in extended regions out to > 10 arcsec from TTS. This is shown by Linsky's comparison of a large aperture IUE spectrum with a much smaller aperture GHRS spectrum of T Tau. Walter showed a long slit STIS spectrum of T Tau that clearly demonstrates that the H_2 emission extends to about > 10 arcsec from the star.
- Most of the UV emission lines are fluorescent lines pumped by the strong Lyman-α line, but for PMS stars the pumping transitions are mostly from the broad red wing of Lyman-α. Ardila and Walter argued that is likely due to the blue wing of the Lyman-α being absorbed by the stellar wind and the red wing being enhanced by accretion. Detailed radiative transfer models are now needed to understand how these fluorescent processes work in detail.
- Herczeg and Ardila found that the H_2 transitions pumped by Lyman-α are from excited vibrational and rotational states within the ground electronic state that have a nonthermal population. What mechanisms produce the nonthermal populations of these states?

Coronal Electron Densities: Ratios of intersystem to forbidden lines of the He-like ions C V, O VII, Ne IX, and Mg XI are typically used to measure coronal electron densities from X-ray spectra. Ness showed that these diagnostics should be treated carefully, because the stellar UV radiation field can populate some levels when a hot star is nearby. This is especially important for C V and O VII. For Ne IX, Mg XI, and Si XIII the inferred electron densities may be sensitive to blended dielectronic satellite lines to each line of the triplets. Also, strong photoionizing radiation fields may alter the level populations for these ions.

Stationary Hot Gas: It now appears that the hot plasma that we see in X-ray spectra of stellar coronae is largely stationary, not, for example, flowing from a star in a dense stellar wind. This is the conclusion that one draws from the absence of Doppler shifts in the coronal lines observed by Chandra from σ^2 CrB as reported by Osten. Also, Redfield showed that FUSE spectra of the Fe XVIII 975 Å line in several stars show no Doppler shift and the lines are not much broader than thermal. Thus the hot coronal plasma is confined, presumably by strong magnetic fields. The coronal winds of active stars must have much smaller densities than the dominant emitting structures, and they must have much smaller emission measures.

Stellar Coronal Structure: Complex magnetic fields should create small scale structures in stellar coronae as is the case for the solar corona, but how can one test this assumption? Binary systems containing a hot white dwarf that is eclipsed by a main sequence companion provide the testbeds for studying fine scale structure in stellar coronae. The best example studied so far is V471 Tau. Walter showed time-resolved STIS spectra of V471 Tau before and after eclipse in which the absorption strengths of the C II, C IV, and Si IV lines change as the white dwarf moves by only its small radius. Also, the strength of the absorption is very different on the two sides of the K dwarf. Are we seeing absorption by prominence-like structures in which 10^5 K gas is confined in thin magnetic flux tubes high above the normal hydrostatic scale height?

Supergiant Winds: Previous models of winds in cool luminous stars assumed spherical symmetry above the stellar chromosphere. Lobel provided us with a new picture of mass flow in an M supergiant (α Ori) based on STIS spectra obtained by stepping a narrow slit across the stellar disk. He showed that the flow depends on position around the star, and that it changes with time from outflow to inflow and then back to outflow. Linsky said that we need a physical model to explain this changing flow pattern that explains both the UV emission lines (hot gas) and the radio emission (cold gas). Also, can Ayres' model of smothered coronae explain the weak Si IV and N V emission lines of cool luminous stars like Arcturus?

New Mass Loss Rates: Wood showed that the Lyman-α absorption toward nearby stars consists of three components – warm interstellar hydrogen, hot red-shifted hydrogen in the outer heliosphere where the interstellar medium and solar wind interact, and hot blue-shifted hydrogen in the astrosphere (or asterosphere if we adhere to a completely Greek compound word) where the interstellar medium and the stellar wind interact. Accurate measurements of the latter component led to the first estimates of mass loss rates from solar-like stars down to 0.2 $\dot{M}_\odot$. He showed that α Cen A+B together have a mass loss rate of about 3×10^{-14} and Proxima Cen has a mass loss rate $< 3 \times 10^{-15} M_\odot$ per year. This technique is opening up a new topic in cool stars research. I find it interesting that $\dot{M}_{\alpha Ori}/\dot{M}_{ProxCen} \sim A_{\alpha Ori}/A_{ProxCen}$! Perhaps Goldberg (1979) was right when he proposed that mass loss rates are proportional to the surface area of a star, even for very different stars that likely have very different mass loss mechanisms.

Spectral Classification of Brown Dwarfs: There is now a good spectral classification sequence from type L0 through T6 using the strengths of H_2O and CH_4 bands in the near-IR (Geballe) and narrow band photometry also in the near-IR (Stephens). The calibration of this sequence in terms of effective temperatures using model atmospheres that contain all of the important opacity sources is proceeding very well, so we are close to obtaining accurate bolometric luminosities from the spectral types.

3. Deep Mysteries

The oral presentations and posters at the meeting also highlighted many unanswered questions, which I hope will be answered by the next workshop:

Dynamos: Despite the extensive literature on theoretical models for stellar dynamos, we still do not understand where the dynamo operates in the Sun or in stars of different spectral type. We need models that include the essential physics and can predict successfully the magnetic properties for a wide range of stars. The session on physical processes left us with several major questions to ponder:

- Are magnetic fields generated primarily at the base of the convective zone, throughout the convective zone, or near the surface?
- Are dynamos qualitatively different between stars with radiative cores like the Sun and without radiative cores like late-M dwarfs and brown dwarfs?
- Why are stellar cycles seen in only about one-third of the inactive solar-like stars?
- Why are no cycles seen in the very active stars?
- Why have cycles not yet been observed in X-rays? Is the reason observational selection or intrinsic? The only evidence presented for a cycle in an active star is Guinan's data for EK Dra.
- Feigelson asked why do dynamo models not predict $L_x \sim M$, which is observed in young stars?

Stellar Meridional Flows: Meridional flows are observed at the surface of the Sun through Doppler measurements and in the interior through helioseismology. Knowledge of these flows is important for understanding the migration of large scale magnetic fields during the cycle, leading to the well-known polarity reversals at the beginning of a new cycle. Also, Judge stated that the solar meridional flow to the poles can power a Babcock-Leighton dynamo. There are theoretical models for meridional flows in stars but no measurements to test these models.

The Rotation-Activity Noncorrelation for PMS Stars: For stars in clusters older than about 10^7 years, L_x/L_{bol} increases with rotation rate reaching saturation near 10^{-3} at high rotation rates. This result is usually considered to be evidence for dynamo generated strong magnetic fields that somehow heat the corona. Feigelson showed, however, that both slow and fast rotators in the young Orion Cluster have saturated X-ray emission. Why? In the Shu *et al.* (1997) model, coronae are heated by the interaction of magnetic fields from the star and the disk. The rotational shear between these two magnetic fields is the energy source that produces flares and coronal heating. While the Orion stars do not have dusty disks observable in the infrared, they may have gaseous disks with embedded magnetic fields that would be hard to detect in the infrared. This could explain why even the slow rotators have saturated X-ray emission.

Angular Momentum Nonconservation: Young stars should spin up as they contract during their evolution to the main sequence. In her study of stars in the Orion Flanking Fields and NGC 2264, Rebull showed that these stars evolve at nearly constant angular velocity rather than conserving angular momentum. Since many of these stars show no evidence for disks, interactions with a disk cannot explain the problem. The time scale for angular momentum loss in winds seems unable to explain this result either. So, we are faced with a mystery.

Saturation: Empirically the most active stars convert about 0.1% of their bolometric luminosity into X-rays, $L_x/L_{bol} \approx 10^{-3}$. What physical processes control this ratio? In his computer simulations of a sun-like star with 30 times the solar magnetic flux input rate, Schrijver showed that essentially the whole corona is covered with strong magnetic fields but $L_x/L_{bol} \approx 10^{-4}$. What makes L_x/L_{bol} increase another factor of 10, and what are the effects in the corona? It is likely that a further increase in the input of magnetic flux leads to more stressed coronal fields and more heat dissipation, but we need good physical models to describe this situation.

FIP Bias, no-FIP Bias, and Inverse-FIP Bias: Magnetic loops in the solar corona and the slow speed wind show enhanced abundances of elements like iron with first ionization potentials less than 10 eV. This is commonly called the FIP effect or FIP bias. There is strong evidence for a FIP bias in solar-like inactive stars, a reverse-FIP bias in very active stars, and no FIP bias in intermediate activity stars. Audard, Güdel, and Linsky described the analysis of X-ray spectra that provided these abundance anomalies. What is the process responsible for the FIP, no-FIP, and reverse-FIP biases? Proposed ideas include the trapping of ions in magnetic field lines (Linsky), electric fields (Güdel), diffusion, and gravitational settling.

Coronal Flux Tubes: TRACE images of the solar corona show very narrow structures often called threads. Do the threads trace magnetic flux tubes, and what physical processes are responsible for the very narrow threads?

- Judge asked why these threads show no evidence for expansion with height in the solar corona?
- Jordan suggested that the threads seen by TRACE are really the cool cores of hotter tubes.
- Is heating mainly at the base of the flux tubes, as argued by Schrijver, or throughout the length of the flux tubes?
- Why are some flux tubes consistent with potential field extrapolations while others are very nonpotential? Hussein showed that potential field extrapolations do not work for the very active star AB Dor. Nonpotential fields require electric currents in the corona, which can

accelerate nonthermal particles leading to such observed phenomena as gyrosynchrotron emission, flares, and explosive events.

- How do the coronal flux tubes trace back through the chromosphere, and into the kinetic energy reservoir of the photosphere?

The log T = 6.8 Bump: Sanz-Forcada and Dupree showed that active stars typically have a sharp peak in their coronal emission measure distributions near $\log T = 6.8$. What controls this? It is likely that thermal conduction prevents the bulk of the gas from getting much hotter because conductive heat transport is very temperature sensitive, whereas the radiative loss rate is nearly independent of temperature at these temperatures.

Ultrahigh Coronal Electron Densities: Line ratios for ions formed in the very hot plasmas in active stellar coronae indicate electron densities ($n_e \approx 10^{13}$ cm^{-3}) and pressures ($n_e T \approx 10^{20}$ cm^{-3}K) that are orders of magnitude larger than are seen in the solar corona (Dupree). Schmitt was skeptical that the electron densities could be this high based on recent Chandra LETGS measurements. If these high densities are confirmed by future studies, what physical processes are responsible for maintaining the remarkably high densities and pressures?

Decreasing Activity at the End of the Main Sequence: The diagnostic $L_{H\alpha}/L_{bol}$ for chromospheric emission peaks at about spectral type M5 and decreases to cooler stars (Hawley). X-ray emission (L_x, L_x/L_{bol}) is also fading in the late-M dwarfs like VB10 and L-dwarfs (Fleming), and flares are not seen in L-dwarfs. However the T5 star 2MASS 1237+6526 appears to be an exception with a very high X-ray luminosity. Young brown dwarfs show evidence of magnetic activity that decays quickly as they age, and even rapidly rotating L- and T-dwarfs in the field show no activity. Is decreasing ionization in the photosphere with decreasing effective temperature or a fundamental change in the interior structure of these stars responsible? Perhaps the end of deuterium burning plays an impotant role in the rate of magnetic field generation in the convective interior.

Atmospheres of L- and T-Dwarfs: As emphasized by Marley, we need a self-consistent treatment of atmospheric structure, chemistry, and dust condensation for these stars. We also need to understand the physics of brown dwarf weather involving clouds and rain. The observed variability in a few L-dwarfs is likely due to changes in the cloud structure rather than to magnetic activity (Gelino).

Planets: Santos asked why are stars with planets metal rich? Is this because stars consume metal rich planets and disks (pollution, cannibalism), or because planets form more easily in metal rich disks?

4. Action Items

Since a major focus of Cool Stars 12 is to chart the future of cool star astrophysics, I would like to direct my final thoughts to this vital topic. Every ten years NASA and the NSF ask the National Academy of Sciences to write a report listing the major science program initiatives in astrophysics that these funding agencies should support during the next decade. The Report of the recent Astronomy Survey Committee (ASC), entitled "Astronomy and Astrophysics in the New Millenium (2000)" is considered by the funding agencies to be the definitive document that clearly states what American astronomers believe to be the critically important scientific goals of the field and what they need in space-based and ground-based instruments and theory to accomplish these goals. This Report is not an isolated document representing only the views of the astronomical community in the US, however, as other strategic planning reports written for ESA, ESO, and other agencies are remarkably similar in their scientific objectives, although implementation plans differ somewhat. The recommendations of the ASC, therefore, describe the environment in which we must live for at least the next 10 years, and they tell us what our astronomical colleagues think about our research area.

The ASC Report lists five key problems that, in their words, are "particularly ripe for advances in this decade." I would paraphrase these key problems as: (1) to determine the large-scale properties of the universe, (2) to study the first stars and galaxies, (3) to understand the formation and evolution of black holes, (4) to study the formation of stars and their planetary systems, and (5) to understand how the astronomical environment affects the Earth. These key problems map onto only a small portion of the contemporary research topics in the field of cool stars, stellar systems and the Sun: in particular, stellar and planetary formation (but not evolution), and the Sun (but only as an external boundary condition to terrestrial climate). This is disturbing.

The recommended major and moderate initiatives in the ASC Report include the Advanced Solar Telescope, Solar Dynamics Observatory, and Frequency Agile Solar Radio Telescope, which are dedicated solar instruments. But there are no instruments that are dedicated to, or primarily designed for, stellar astronomy. Many of the recommended major new instruments can and will be used for stellar observations (e.g., Next Generation Space Telescope, Constellation-X Observatory, and Expanded Very Large Array), but the amount of observing time assigned to stellar observations will be limited and synoptic programs will be especially difficult to get approved. Future ESA projects like FIRST and XEUS also offer important but limited observing opportunities. New and future instruments on ground-based optical/IR telescopes and the proposed ALMA and SKA radio arrays will provide important opportunities, but again the question of access to the cool star community is a fundamental issue.

Why are there no major instruments coming on line that are dedicated to stellar astronomy? An even more important question is, why there are no approved future satellites that can obtain UV spectra after the end of the Hubble mission in 2010? There are ideas for dedicated missions discussed this morning like the Stellar Imager, but these are not yet approved missions. I believe that we can do far better in the future by aggressively pursuing the following strategies and tactics:

More Students: The future of the field will be in the hands of the students that we educate and supervise. Unfortunately, many of the active researchers in the field have no students because they are at observatories or industrial or government laboratories that are not closely connected with a university. In many cases, astronomers working outside of universities can get adjoint appointments at a neighboring university that will enable them to teach part time and advise students. This requires additional effort, but the long-term rewards are great. Also, there are several recent examples of universities setting up new programs in solar and stellar astronomy as a result of the strong efforts by active individuals.

Better Publicity: It is very impotant to describe the major advances in the field to our astronomer colleagues and the general public. Universities and astronomy organizations like the IAU and the AAS have experts who can help us write press releases and distribute them to the media. Large scientific meetings provide good opportunities for presenting new discoveries because media people often attend. My experience is that journalists are almost always interested in writing about new results when there is a good story to tell. Well prepared visuals are particularly important in generating interest in our work. Good publicity concerning major discoveries tells the world that our field is exciting. I suggest that the organizers of Cool Stars 13 give serious thought to publicizing the major results presented at the meeting.

Improved Self-image: After one's carefully written proposal for observing time on a large telescope is rejected, it is only natural to feel negative, but the reality is that many of the best research programs in solar and stellar astronomy eventually are approved when the proposers are clever and persistent. A rejection should be considered a stimulus for doing better on the next opportunity. If our self-image is good, then we will succeed. In my summary talk at IAU Symposium No. 176 "Stellar Surface Structure" in Vienna (October 9–13, 1995), I showed a cartoon distributed during a student strike at the University of Vienna. This cartoon (Fig. 1) shows a fat pig, symbolizing the Austrian bureaucracy, consuming all of the food (money) that the starving student needs to pay for his expenses. No doubt, many of you looking at this cartoon see yourselves as the poor student competing unequally with the fat pig (the extragalactic astronomers) for the limited resources (observing time and money) in the trough. If so, you are wrong. I believe that we are solving many of the vital questions of contemporary astrophysics. We need to convince our colleagues that our work provides direct tests of fundamental physics concerning the interaction of magnetic fields, ionized plasmas, fluid motions, and radiation that are fundamental to all of astrophysics. We need a good strategy (see below) for presenting our work and persistence to be successful.

Strategy: Many programs in astronomy are producing large data bases that potentially are very useful for stellar astronomy, although the data were obtained for unrelated purposes. Examples include 2MASS, DENIS, and OGLE. These data bases can and should be mined for other purposes. Higher spatial, spectral, and temporal resolution is now becoming available on large ground-based telescopes. New spectral regions (e.g., IR, sub-mm, mm) also are opening up and can be useful for stellar astronomy. Robotic telescopes are now important tools for coordinated multiwavelength observations, and for monitoring stars with photometry and spectroscopy. Schrijver showed that computer simulations of stellar phenomena obtained by extrapolating solar models with different parameter values are very useful in understanding stellar phenomenology, but also are valuable for demonstrating what stellar phenomena are likely to be observable with good sensitivity. This is important for proposals requesting observing time. Finally, I mention that scientific cartoons, that is simplified diagrams showing how physical processes produce observed phenomena, can be important intellectual tools. Well conceived cartoons stick in peoples' minds and have a strong influence on our physical intuition.

Marketing: This term sounds like it is totally inappropriate for scientific research. The opposite is true. Studies of the Sun and late-type stars have several markets and these markets need to be contacted often to obtain appropriate support. One obvious market is the need to understand the relation between solar radiation and terrestrial climate. Since solar ultraviolet radiation has an important influence on the terrestrial atmosphere, we need to monitor and understand the physical processes responsible for the creation of the solar UV spectrum. The formation of stars and planetary systems fits nicely into NASA's theme of "origins," but understanding how PMS stars evolve into sun-like nonactive stars is also critically important for understanding the present day Sun. As previously mentioned, the study of late-type stars can provide insights concerning the interaction of magnetic fields, fluids, and radiation that underlies a broad range of phenomena throughout the cosmos. Thus research on the Sun and late-type stars relate directly to the major themes of physics and astrophysics. We need to emphasize this point over and over again.

Infiltrate the Power Centers: This is not a facetious comment. Very often new large programs happen only because an individual working inside a funding agency, or on an advisory committee, makes it happen. When talented visionary people accept the responsibility to work for a time at an agency like NASA, then new programs of interest to our field are implemented. Consider this when planning your future.

Sales: Hang together or hang separately.

Go forth: To paraphrase the cartoon character Pogo, "We have met the future of cool star astrophysics, and it is us." I have listed a number of ways in which we can reach a very productive future, but this is possible only to the extent that we make it happen. Go forth and prosper.

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Figure 1. A portion of a strike manifesto handed out by students at the University of Vienna during IAU Symposium No. 176 in October 1995. See subsection on “Improved Self-image”.

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