
Conference Summary

SUMMARY OF IAU SYMPOSIUM 176

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Abstract.

This IAU Symposium 176 on the topic “Stellar Surface Structure” provided a much needed opportunity for instrumentalists, observers, and theoreticians to present their exciting new results and to preview the even more exciting future for high-resolution imaging of stellar surfaces. I will attempt a critical summary of this symposium by calling attention to those areas that will likely be very productive in the future and by discussing some important topics that have not been addressed adequately to date, such as the roles of systematic and random errors, the true nature of the solar-stellar connection, and the physical processes responsible for stellar surface structure.

Lesser artists borrow, great artists steal. *Igor Stravinsky*
You never can tell. *George Bernard Shaw*

1. First Thoughts

One is challenged to summarize adequately the essentials of a five-day scientific meeting immediately following many excellent oral and poster presentations. Summarizing this IAU Symposium on Stellar Surface Structure is particularly challenging because of the unusually high quality of the presentations and the innovative projects that seek to extract information beyond the diffraction limit of the largest optical telescopes. Perhaps the motto of this conference should be “*Deus ex machina*” or “*L’ordinateur sera la vérité.*”

I am amazed and stimulated by what has and may soon be accomplished. Nevertheless, we should retain a healthy skepticism concerning what is being touted as knowledge, because the mind’s eye is easily de-



Figure 1. A breakfast table scene in the Schloss Schönbrunn outside of Vienna.

ceived by biases that should be recognized as systematic errors. I will provide some examples of this later. Since the essence of this symposium is imaging, I will illustrate my main points with images of our beautiful and historic environment—Vienna.

We have been impressed by the flawless planning with fine attention to detail shown by Klaus Strassmeier and the Local Organizing Committee. An image that expresses their artistic professionalism is a picture of the gracefully folded napkins on the dining room tables at the Schloss Schönbrunn shown in Figure 1. According to my tour guide, the technique for wrapping these napkins in the style fit for an emperor is an Austrian state secret known to only two people. I believe that Klaus must be one of these people because the symposium was infused with the elegant style represented by these napkins.

Although this is the first IAU symposium on the topic of stellar surface structure, our meeting is actually the second on this topic. On 1990 July 24–27, Armagh Observatory hosted a meeting on “Surface Inhomogeneities on Late-type Stars.” A comparison of the two meetings measures the rapid

progress in the field over the past 5 years. At the Armagh meeting (see Byrne and Mullan 1992) 77 participants presented 31 oral and 32 poster papers, but at this meeting the more than 200 participants presented a total of 54 oral and 102 poster presentations. Perhaps more to the point is the broader range of topics covered at this symposium, which includes OB- and chemically peculiar B-type stars, optical and radio interferometry, and new image reconstruction techniques. I was particularly pleased by the results obtained by using these techniques, presented as images and videos. Clearly the field of stellar surface structure is maturing rapidly, but the greatest progress probably lies in the future.

Throughout the meeting the term “solar-stellar connection” was used often but, in my opinion, without careful thought. To what extent and at what level is the Sun our role model, our Rosetta stone? I see three levels at which the connection can be made:

The Solar-Stellar Physics Connection. By this I mean that the laws of physics (e.g., Maxwell’s equations, gravity, hydrodynamics, radiation processes) must apply to both the Sun and stars. We all agree that the same physical principles should apply to the Sun and to late-type stars, but the beautiful data presented at this meeting quantitatively and often qualitatively differ from what is typically observed on the Sun. Unfortunately too little time at this meeting was devoted to the application of physical principles needed to understand the data, signifying the present immaturity of the field.

The Solar-Stellar Phenomenology Connection. This term refers to the similar phenomena (including flares, plages, prominences, granules, spots, chromospheres, transition regions, and coronae) observed on the Sun and late-type stars. However, the length, energy, and time scales of these phenomena differ enormously between the Sun and active late-type stars. For example, flares on RS CVn systems and PMS stars can be 10^4 times more energetic than even large solar flares, and spots can cover up to 56% of the stellar surface, as was shown for II Peg by O’Neal, Neff, Piskunov, & Saar,¹ compared to $\approx 1\%$ at solar maximum. Gyrosynchrotron radio emission, which is usually observed from active stars, is detected from the Sun only during flares. Thus the solar-stellar phenomenology connection is unclear for the more active stars.

The Solar-Stellar Toolkit Connection. Schrijver called attention to the commonality of diagnostic correlations of observed quantities that relate solar and stellar data. In particular, emission-line fluxes, after subtraction of the basal flux level that depends only on T_{eff} and gravity,

¹In this paper, citations with names but not dates refer to oral or poster presentations at this symposium, which are included in this volume.

are tightly correlated with the corresponding fluxes of other emission lines (diagnostic of heating in different layers of the atmosphere), X-rays, magnetic fluxes, and rotation by power laws. He refers to these power laws as the solar-stellar “toolkit” because they describe generically the response of an atmosphere to magnetic heating and radiative cooling. The toolkit thus implicitly contains the solar-stellar physics connection but is not specific because, in principle, different heating mechanisms can have the same atmospheric response. One component of the toolkit is the concept of saturated heating seen in chromospheric lines and coronal X-ray emission.

Nobody at this symposium asked why there should be a solar-stellar phenomenology connection. The observations of stellar phenomena on vastly different scales (length, energy, and time) from what is typically seen on the Sun argue that the phenomenology connection is often tenuous at best. One should ask why there is any phenomenology connection at all. I raise this question because many of the physical processes, especially those involving magnetic fields and fluid motions, are inherently nonlinear, and instabilities can play important roles. Thus the phenomena depend on initial conditions, boundary values, and the geometry. Small changes in the initial conditions (such as the heating rate) can amplify with time much like the terrestrial weather, in which case the response of the atmosphere to small changes may be hard to predict. Also changes in scale or density can change the importance of horizontal radiative transfer to amplify or suppress phenomena seen on the Sun. Thus we should expect to see, and do indeed see, some stellar phenomena that are qualitatively different from what is observed on the Sun.

Several times during the meeting we have seen examples of apparent agreement between observation and theory. As Dravins pointed out, this can be dangerous. Theoreticians then upgrade their crude speculations by calling them “theories.” An example is Schüssler promoting his speculations concerning the emergence of magnetic flux at high latitudes in rapidly rotating active stars to the rank of a theory after Vogt’s presentation of evidence for the polar migration of starspots shown by Doppler and Zeeman-Doppler images of HR 1099. An undesirable aspect of agreement is that theoreticians may stop thinking about a “solved” problem, and observers likely will cease getting telescope time as time-allocation committees view these topics as “solved” problems and therefore uninteresting. As Dravins said, “We need an elaborate theory that disagrees with sophisticated observations.”

Many speakers referred to the “information content of data.” What is “information”? To my mind, information refers to numbers that describe something more precisely by providing details such as the location and size of a starspot. Information has a dimensionality of zero (one number) or one

(a string of numbers). To be useful such numbers should include random errors describing measurement uncertainty and systematic errors representing the effects of uncertainties of the assumptions underlying the measurement technique. With very few exceptions, neither random nor systematic errors were provided in any of the papers presented at this symposium. I urge researchers to estimate and present the errors in their results so that we can determine which proposed surface structures can be believed.

By comparison, “knowledge” refers to a pattern or model into which the “information” can be placed in order to understand its context. Knowledge is essentially a two-dimensional mental image as the mind naturally assembles information into patterns or images. Images are powerful because they are retained for a long time and often determine whether one accepts or rejects data as valid information. However, the mind is easily deceived by conventional wisdom, perceived beauty, repetition (the “big lie”), higher authority, or sloth. As an example, I mention the by-now-famous image of magnetic fields that interconnect both stars in a close binary system. This image, first proposed by Uchida and Sakurai (1983), has been presented at many conferences and has been invoked to explain stellar flares and other phenomena. This image is interesting, plausible, beautiful, and easily remembered. Although it has the ring of truth and is accepted by many as a paradigm, it has never been verified, and it cannot be accurate in detail because it is based on a potential field extrapolation.

Vogt presented a very interesting image of the magnetic field of a rapidly rotating star in an RS CVn system. This image shows a star with magnetic polar caps and a toroidal magnetic field connecting the equatorial and polar regions with newly emerging flux moving along the field lines from the equator to the poles. This image, based on Doppler and Zeeman-Doppler images of HR 1099, could become the next paradigm for the magnetic field structure of active stars. Although the image may be close to describing the magnetic field structure of these active stars, Byrne keeps reminding us that the inference of polar spots on these stars is based on many crude assumptions and is thus subject to large systematic errors.

2. Quotable Quotes

Before discussing the other important issues presented at this symposium, I have the pleasure of reminding you what some of the speakers actually said. The following quotes, which I list without comment, capture the flavor of the meeting and in some cases convey the irony or deeper meaning of what was on each speaker’s mind.

David Gray: “Astronomers are real people, people with a heart.”

Karel Schrijver: “We can use the Sun as a paradigm and hold onto it as long as we can.”

David Gray: “We want to eke out the last bit of information from the spectra.”

William Wehlau (present in spirit): “Doppler imaging is the pinnacle of achievement in stellar spectroscopy.”

Martin Stift: “It is better to have no map than a spurious map.”

Steve Vogt: “Twenty-three pictures are worth twenty-three thousand words and it will take me six years to tell you about them.”

Manfred Schüssler: “Can theory explain the beautiful starspot data?”

Robert Rutten: “Really interesting phenomena lie to the right of the line describing the limit of what can be observed from the ground: flux tubes, current sheets, double layers, [and heating].”

Bert van den Oord: “Since loops are nearly isothermal, differential emission measure analysis can tell us nothing about the heating function.”

Rob Jeffries: “There is very little information in an X-ray light curve.”

Martin Kürster: “Most of the X-ray emission data that we now have contain very little spatial information.”

Dainis Dravins: “Concepts like the mixing length do not exist in nature; therefore, quantities like the Rossby number do not exist.”

David Mozurkewich: “Betelgeuse and Mira are too big to observe.”

John Baldwin: “One needs at least three photons for the phase closure.”

Robert Donahue: “Another one hundred years of data on this star will be exciting.”

3. Why Do Stars Have Surface Structure?

The existence of brightness variations across the surfaces of stars challenges theoreticians to provide plausible explanations. Unfortunately, there are now very few detailed explanations for what has been observed and no predictions of what will be observed in the future. In order to stimulate the development of theory, I will summarize some ideas that were presented during the symposium and suggest how they should be developed.

Schwarzschild (1975) predicted that low-gravity stars (e.g., supergiants) should have only a few convective cells on their surfaces, whereas high-gravity dwarfs like the Sun should have a very large number of granules at any one time. Thus one would expect to see one or a few hotter granules on the surfaces of the large-angular-diameter supergiants such as α Ori and Mira, which can be resolved with large telescopes. Indeed, a bright feature or features have been seen on the surface of α Ori by using the FOC on HST operating in the near-ultraviolet (Gilliland), speckle imaging with the 4.2 m Herschel Telescope (Klückers *et al.*), and Fizeau interferometry

with the same telescope (Wilson *et al.*). Although these three experiments were performed at about the same time, they do not agree on the number of bright regions, their location on the stellar surface, or their brightness contrast with their surroundings. Clearly these techniques should be refined and tested by contemporaneous observations of the same targets. Also we need predictions of the temperature contrast between the centers and edges of granules in low-gravity stars.

A number of speakers (in particular, Collier-Cameron) reminded us that magnetic fields in low-density plasmas such as stellar coronae can determine the brightness distribution in the UV and X-rays by controlling the local magnetic heating rates, confining the plasma, thermally insulating the plasma from its environment, and channeling thermal conduction from the corona. Although all of this is true and important, it does not answer the question of why stars have surface structure because the structure of the magnetic fields is controlled by other processes including convection. This points out the need for theoretical studies of the scales of magnetic field structures in different types of stars with different rotation rates and different convective zone properties.

Ayres reminded us that the formation of CO and perhaps other molecules can lead to thermal instabilities above the photosphere in stars cooler than about $T_{\text{eff}} = 6,000$ K. The effect is to amplify thermal fluctuations associated with time-dependent heating processes, because radiative cooling leads to enhanced molecule formation and thus more cooling. The importance of this instability for enhancing brightness variations across a stellar surface depends on the time scales for heating and CO formation/destruction, horizontal radiative transfer, and hydrodynamics, in addition to the T_{eff} , gravity, and chemical composition of the star. The inclusion of the CO radiative instability into model atmosphere codes with time-dependent heating was mentioned in the talks by Avrett and Cuntz.

Flows in complex gravitational fields, such as gas streams and instabilities in accretion disks for cataclysmic variable and Algol systems, are a fourth mechanism for creating brightness distributions across the surface of stars. In all likelihood there are other mechanisms responsible for creating stellar surface structures that should also be investigated. This is an important underexplored field.

4. Some Examples of Bias in Image Reconstruction

Before assessing the image reconstruction techniques presented at this symposium, I would like to point out how one's biases can interfere with the interpretation of images. Figure 2 is a detail of a very large painting of a wedding reception at the time of Empress Maria Theresia. Near the center



Figure 2. A small portion of a painting of a 1760 wedding reception in the Schloss Schönbrunn showing the five-year-old Wolfgang Amadeus Mozart.

of this detail is the five-year-old Wolfgang Amadeus Mozart, a favorite of the Court. The entire painting, containing some 600 people, could not have been painted at the time, but was instead completed years later from individual portraits of each person. This scene is easily accepted as fact because Mozart was indeed five years old at the time, but the reality is that he was not present, and he was included for reasons of political correctness. The observer is easily fooled by this bias in image reconstruction.

As an experiment I have selected two images, both of which are familiar to many of you, and have projected them very far out of focus (see Fig. 3) to illustrate the limited resolution now available for studying stellar surface structure. The human mind tries to find “structure” in poorly resolved images, and our biases play a major role in shaping our ideas about what is contained in these images. What do you think these images are? Now look at Figure 4 (on the following page), which shows the images in somewhat better focus, but please do not look at the later figures to keep the experiment honest. Try to guess the true image with only the few resolution elements provided by the out-of-focus image. With better focus (the equivalent of more resolution elements) in Figure 5 one can guess again. Finally, I show in Figure 6 the fully resolved images.

There are some important lessons that can be learned from this experiment. First, one can be easily fooled because the largest structures, which may be the least interesting (for example, the newspaper), dominate the

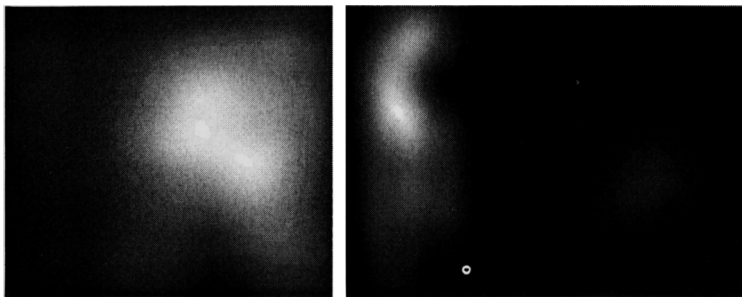


Figure 3. Two out-of-focus images containing very few spatial resolution elements.

out-of-focus image of Sigmund Freud, or the two telescopes near each other appear as one object in the other out-of-focus image. Second, one looks for structures with up-down orientation, whereas the real image may have a different orientation. Third, the most interesting structures may not appear until the image is in excellent focus. For example, the stars do not appear until the final image. Finally, it is important to check the fidelity of image reconstruction techniques by comparison when feasible with unreconstructed (i.e., direct) images. Please consider these points as we try to understand poorly resolved (i.e., out-of-focus) images of stellar surfaces.

5. Image Reconstruction Techniques and Applications: An Assessment of the Field Today

A major portion of the symposium was devoted to the broad and rapidly maturing set of techniques for inferring the spatial distribution across a stellar surface in brightness, magnetic field properties, or chemical composition with much higher spatial resolution than is permitted by the stellar seeing disk. I would like to add my assessment of the very clever ideas and results presented during the symposium.

Rice, Unruh, Piskunov, Vogt, and others discussed the **Doppler Imaging** technique and its applications to Ap, RS CVn, dMe, PMS, and Pleiades dwarfs. Various inversion techniques using different regularization schemes appear to give consistent results, provided one has excellent phase coverage (a point emphasized by Piskunov) and high S/N. We were entertained by the impressive video of the brightness distribution of ER Vul during several orbits (Piskunov), 11 years in the spotted life of the HR 1099 (Vogt), spots on the surfaces of Pleiades G and K dwarfs (Stout-Batalha), and the agreement between the magnetic and abundance maps of the Ap star ϵ UMa (Hatzes). Unfortunately, none of the beautiful images was accompanied by error images to show which features can be believed given the measure-

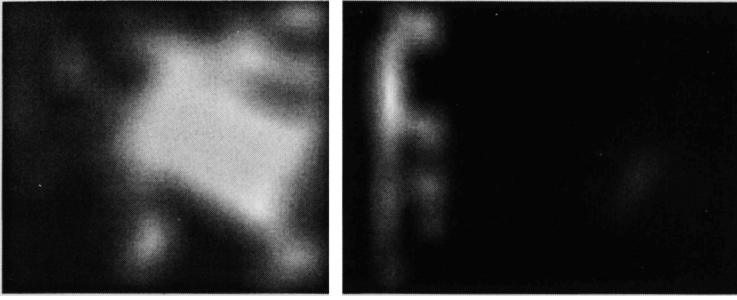


Figure 4. The same two images as in Figure 3 but closer to focus.

ment errors. An even more important concern is that we may be lulled by the beauty of the images (especially when they are in color) into ignoring systematic errors. Unruh, Strassmeier, and Byrne reminded us that errors in the assumed stellar parameters (e.g., line profile shapes, uncertain inclination angle, line blends, different thermal structures in the bright and dark regions, etc.) can corrupt the images with false features. Fortunately, the known systematic distortions produced by incorrect assumptions can be used to refine the stellar parameters, and in the near future we will have to correct for errors in the atmospheric models and the inhomogeneity of the S/N and the spectral and temporal resolution of the data. Simulations can be useful in estimating the range of possible corruptions in the images (also called systematic errors) when sensible ranges in these uncertain stellar parameters are taken into account (cf., Rice 1991).

Zeeman-Doppler imaging is the application of Doppler imaging techniques to spectra obtained in opposite senses of circular polarization to infer the vector magnetic field. Donati showed that by combining together more than 1000 spectral lines into a composite profile, one can obtain the required $S/N > 1000$ for this technique to work. Although this promising technique should be developed further, it contains many approximations such as a Milne-Eddington model atmosphere and separate solutions for the temperature and magnetic field images. We have seen no estimates of errors and the results so far on HR 1099, if credible, raise the question of why regions of strong magnetic field and low temperature are not correlated. Another variant of Doppler imaging is the new technique of **differential interferometry imaging**, which uses displacements in the absorption line centroid to identify the location of dark or bright regions on a stellar surface. Petrov presented this interesting technique, but determining its usefulness awaits its application to real data.

Eclipses of one star by another or of portions of an accretion disk by a companion star provide the necessary information for **eclipse mapping**.

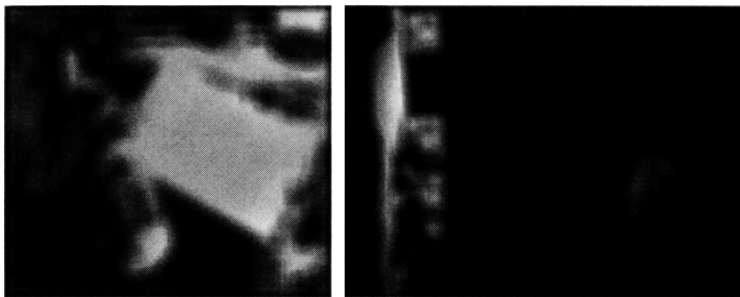


Figure 5. The same two images as in Figure 3 but still closer to focus.

Applications of this technique to the analysis of X-ray emission from YY Gem, AR Lac, and other eclipsing systems led Schmitt to the important conclusion that there is no evidence for extended hot ($> 10^6$ K) plasma in stellar coronae. This is the first hard evidence that the X-ray emitting hot thermal plasma in stellar coronae is not appreciably extended. René Rutten showed how eclipse mapping can provide spectra as a function of radial position in an accretion disk in cataclysmic variable systems to infer the thermal properties of the disk and to study spectral line formation.

Neff and Walter brought us up to speed on the **emission-line mapping** technique in which one infers the location of bright plage regions in the chromosphere of a rapidly rotating star from the migration of emission bumps superimposed on the Mg II or other emission lines from the blue to the red wing as the star rotates. This technique can provide evidence for the rotational modulation of plage regions, if temporal variations in the line flux and shape due to flares or intrinsic variability are small compared to the changes in the composite line profile resulting from the rotation of a star with a fixed inhomogeneous brightness distribution. Alas, flares often dominate the time variability signal for the active stars (typically RS CVns) that have been studied recently, and we await good maps of the chromospheric plage structure on these stars. The absence of rotational modulation, as pointed out by Schrijver, does not disprove the solar analogy, provided one thinks in terms of the solar-stellar toolkit connection.

Periodic variations in circumstellar absorption features can be used to identify long-lived condensations or shocks in stellar winds that repeat at the same rotational phase. Eaton showed how this **wind mapping** technique can be used to study structures in the winds of cool supergiants, and the technique can also be applied to the winds of OB stars.

Collier-Cameron reviewed the evidence for analogs of solar active prominences in stellar postflare spectra and X-ray light curves and for analogs of solar quiescent prominences obtained from the analysis of the spectra

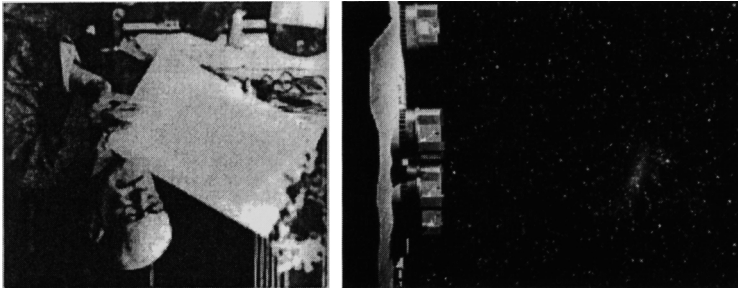


Figure 6. The same two images as in Figure 3 but now in focus.

of rapidly rotating stars such as AB Dor. Analysis of **dynamic spectra** of AB Dor has identified large prominences located at or just beyond the corotation radius of the star with masses 100–1000 times that of large solar prominences. Large structures such as these may play a key role in mass and angular momentum loss from young, rapidly rotating stars.

With an impressive video, Richards demonstrated that **Doppler tomography** of Algols, other interacting binaries, and RS CVns is feasible using the information contained in the repeating phase variations of $H\alpha$ difference profiles (individual spectra divided by the mean). She used a Fourier-filtered back projection scheme to identify the gas stream and accretion disk of Algol and regions of enhanced chromospheric emission (i.e., plages) on RS Vul and HR 1099. This work assumes that the $H\alpha$ line is always optically thick, but as Byrne pointed out, this assumption may not be as accurate.

There were a number of presentations on the accomplishments and future plans for **interferometric imaging** of stellar surfaces using multiple apertures at optical and infrared wavelengths. These included presentations on the Navy Prototype Optical Interferometer (Mozurkewich) and the Cambridge interferometer (Baldwin), which are both operational, and ESO's VLT interferometer (von der L u he) now being designed. These instruments may be providing submilliarcsecond resolution images in the next few years, and the NPOI is already capable of obtaining images with a resolution of 3 milliarcseconds. At this stage in the rapid development of the field, the previously formidable problems of phase closure, signal processing, and achieving high signal/noise on sixth magnitude stars are believed to be solved and the extension to much fainter stars is under way. What then is the fundamental limitation in this technique? Since fringe contrast decreases with increasing baseline (needed for higher resolution), the fundamental limitation may be the finite amplitude and small size scale of the brightness contrast across stellar surfaces. These quantities are presently

unknown, but I am optimistic that brightness contrasts will increase as one can resolve smaller structures because the intrinsic scales of convective and magnetic structures could be small even on active stars such as the Sun. If this is true, then interferometric imaging with very long baselines (perhaps kilometers in length) will eventually provide microarcsecond images of stars. This will be truly spectacular!

6. Future Objectives for Studies of Stellar Surface Structure

Since the previous meeting on this topic occurred five years ago, the next important symposium on this topic may occur in the year 2000. At this millennial meeting I would hope that the major breakthroughs presented at this symposium will be exploited and some major unsolved problems will be addressed to provide a plethora of exciting results. A few areas that strike me as most interesting follow:

- We have seen tantalizing glimpses of the brightness distribution of a few stars, but the images have very few resolution elements, and the results, in the case of α Ori, are in conflict. Is the temperature contrast between the bright feature and the mean photosphere as large as the HST data imply? I anticipate major advances in high-resolution imaging during the next five years. As a consequence, the development of theories of stellar surface structure with predictive power are needed urgently.
- The roles that gravity inversion appear to play in disrupting magnetic structures in the coronae of spectroscopic binaries and rapidly rotating stars is an important physical process identified at this meeting by van den Oord and Collier-Cameron. Gravity inversion apparently can be identified in the differential emission measure of a coronal loop, and the peak temperature of a loop may occur in such inversions. This topic requires both additional observational and theoretical studies.
- Rob Rutten and Avrett provided examples of the highly dynamic nature of wave heating and why the concept of a steady chromospheric temperature rise is no longer meaningful at least for nonmagnetic regions. Now that this important point has been demonstrated, we need dynamic atmospheric models for the whole range of late-type stars.
- Although intuition (based on solar analogy) tells us that heating (and thus bright emission from the chromosphere and corona) should occur where magnetic fields are strong, there has been little evidence published so far of correlations between brightness images (showing the location of starspots) and plages seen in chromospheric emission lines. Catalano, however, showed that the $H\alpha$ equivalent width in difference spectra often varies out of phase with the visual magnitude of active stars, showing that the heating rate and the magnetic flux may well

be spatially correlated. He made a good case for this by using observations of the RS CVn-type system UX Ari, but in this system the spots appear to lead the plages by 30° – 50° . Why? This and other projects to study the spatial relation between heating and magnetic fields could be an important topic for the next meeting.

- Several techniques have been applied recently to determine the sense and magnitude of differential rotation in rapidly rotating stars, although purely photometric techniques may not provide reliable information on the latitude drift of spots. Fourier analysis appears to be a promising technique of the future (Lanza & Rodonò). Surprisingly, the magnitude of differential rotation is very much less in RS CVn systems such as HR 1099 than in the Sun and the sense is opposite to that of the Sun (i.e., the poles rotate faster than the equator). Vogt showed Doppler images of this system that show emerging magnetic regions moving toward the polar spots and the poles rotating synchronously with the orbital period. Long duration studies of other systems and rapidly rotating single stars are needed to confirm this conclusion, and theoretical studies are needed urgently to make sense out of these counter-intuitive results.
- Hopefully, during the next five years some answers will appear for major questions concerning the properties of magnetic fields that clearly play a major role in defining stellar surface structures. For example, we need to know why the average magnetic field strength on the Sun is independent of scale size (Solanki) and why large spots appear on stellar surface at Rossby numbers [if they are real] just slightly smaller than for the Sun (Hall)? Also, what are the strengths of starspot magnetic fields (Saar) and why do starspots move toward higher latitudes with more rapid rotation (Strassmeier).
- Finally, Dravins showed us that convection is very inhomogenous and violent. His hydrodynamic simulations explain beautifully the line shifts, line shapes, and the nonthermal line broadening that in the past had been characterized in an *ad hoc* way as Gaussian microturbulence and macroturbulence. I look forward at the next meeting to seeing corresponding simulations for cool stars of different effective temperatures and luminosities, including the M supergiants.

7. How Should We View the Future?

Despite the rapid advances in the techniques for studying stellar surface structure presented at this symposium, some people have expressed concern that these techniques will not be exploited fully because nearly all of the observing time on the new generation of large telescopes will go to ex-



Figure 7. A cartoon distributed during a student strike at the University of Vienna.

tragalactic observers. This concern can be expressed in my final image. As you recall, there was a student strike at the University of Vienna during the symposium to protest decreased state funding for students. Figure 7 shows the cartoon in the strikers' manifesto that illustrates their image of the unequal competition for taxpayer-provided money between the Austrian bureaucracy (portrayed as a pig with the symbol of the state of Austria on its side) and a poor (starving?) student. Perhaps some of you see yourselves in the position of the poor student, the extragalactic astronomers as the fat pig, and the trough representing the observing time on large telescopes. I personally do not view the future in this way. With the many innovative observing techniques now becoming available and the unknown surface structures waiting to be studied, I am optimistic that the experts seated here will acquire the observing time needed to pursue the field vigorously and successfully. Once again to the ramparts. *Veni, vidi, vici*.

I would like to thank the symposium organizers for providing the stimulating program and the delightful social activities. I thank NASA for providing travel support through grant S-56460-D, as well as Dr. N. Piskunov for his superlative image processing skills. I also thank ESO for permission to use their picture of the VLT. Figures 1 and 2 are processed versions of figures in the guidebook Schloss Schönbrunn published by Schloss Schönbrunn Kultur- und Betriebsges.m.b.H.

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