cosmological problems. Admittedly, we are still at the beginning of the road, but the interplay between particle physics and cosmology may indeed lead us to a deeper understanding of the fundamental laws of nature.

A most remarkable paper was presented by S. W. Hawking (Cambridge) who showed that, under certain plausible assumptions, the Universe may be described by a wave function obeying a simple Schrödinger equation such that the most probable state would correspond to an oscillating model universe, singularity free, which is initially inflating and where the entropy does not change with time.

The Symposium ended with two concluding lectures by M. J. Rees (Cambridge) and J. Ellis (CERN) respectively, who summarized beautifully the main items discussed during the meeting and set the perspective for future work from the astrophysicist's and particle physicist's standpoint.

Chromospheric Emission, Rotation and X-ray Coronae of Late-type Stars

R. Pallavicini, Arcetri Astrophysical Observatory, Florence, Italy

In a short note which appeared in 1913 in the *Astrophysical Journal,* G. Eberhard and K. Schwarzschild reported on the observation of emission reversals at the centre of K line of Ca II in some bright late-type stars (Arcturus, Aldebaran, σ Gem). They also noticed that the same phenomenon is usually observed in active regions on the Sun. To my knowledge, this was the first time that chromospheric emission was reported from stars other than the Sun. Since those early days our knowledge of stellar chromospheres has enormously increased, mainly through systematic surveys in the H and K lines of Ca II. More recently, observations at UV and X-ray wavelengths from space have provided ample evidence that chromospheres, transition regions and coronae are common to stars throughout the HR diagram. What is more significant is that these observations have demonstrated that magnetic fields play a fundamental role in the heating of outer stellar atmospheres and that the observed emission levels are in strong qualitative and quantitative disagreement with the predictions of the standard theory of coronal formation via the generation and dissipation of acoustic waves. The emphasis at present is on heating mechanisms which are based on the stressing and dissipation of magnetic fields generated by dynamo action in subphotospheric convection zones. As a result of this, stellar rotation has come to play a central role in the heating problem, as a controlling factor of the efficiency of the dynamo process. It can be anticipated that in the near future new accurate determinations of stellar rotation rates, as well as new measurements of transition regions and coronal emission from space will substantially increase our understanding of the process of coronal magnetic heating in late-type stars.

Chromospheric and Coronal Heating

In the solar atmosphere, the temperature, after decreasing outwards to a minimum value of ≃ 4,500 K in the upper photosphere, starts to rise again, reaching 10^4 K in the chromosphere and more than one million degrees in the corona. Since heat cannot flow from lower to higher temperature regions (second law of thermodynamics) the observed temperature rise requires a non-thermal energy flux to be added to the thermal flux generated by thermonuclear reactions in the core of the Sun and flowing outwards under the form of radiation and convection. For stars of spectral type later than early F—stars which are known on theoretical grounds to possess outer convection zones—the required energy flux has been traditionally ascribed to the generation of acoustic waves by turbulent motions in the convection zone. These waves, propagating in an atmosphere of rapidly decreasing density, steepen into shocks and dissipate their kinetic energy into thermal energy, thus producing the observed temperature rise.

In its simplest formulation this theory, first suggested by L. Biermann and M. Schwarzschild in the late forties and since then universally accepted, neglects the presence of magnetic fields which are considered as an unnecessary, easily avoidable, complication. Consequently, generation of acoustic waves and heating of outer stellar atmospheres are supposed to be spatially homogeneous and temporally constant, at variance with spatially resolved observations of the Sun, which show the chromosphere and corona to be both highly structured and time variable. For example, Fig. 1 shows a spectroheliogram of the Sun obtained in the K line of Ca II. Enhanced chromospheric emission is observed from magnetically disturbed active regions ("plages"), as well as from the

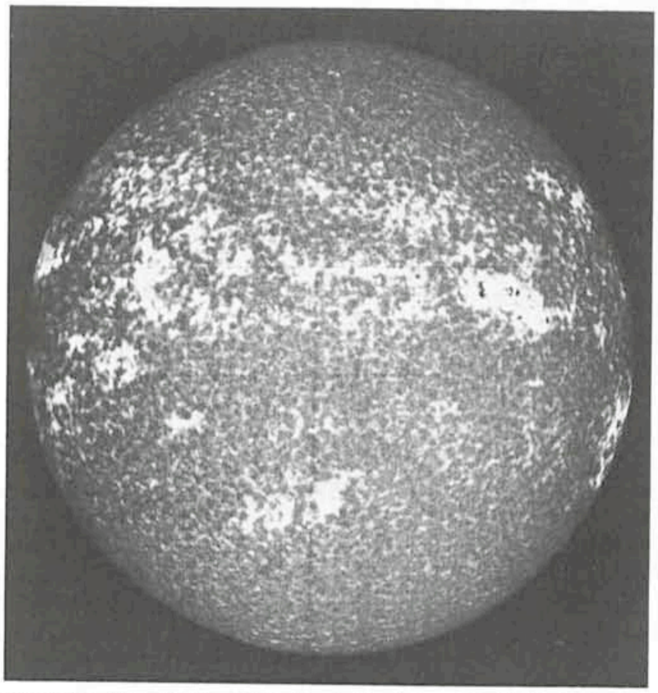

Fig. 1: *Spectroheliogram of the Sun in the K line of Ca II obtained at the Solar Tower of the Arcetri Observatory. Notice the enhanced emission from the chromospheric network and from magnetically disturbed active regions.*

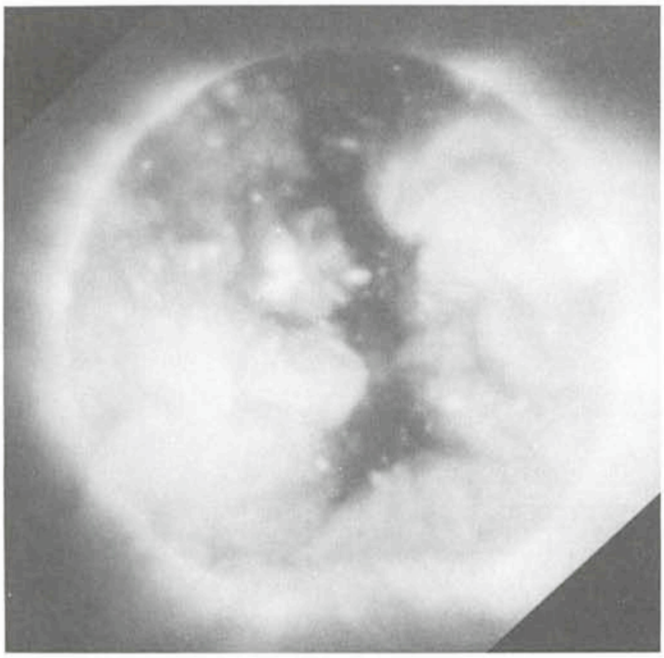

Fig. 2: *X-ray photograph of the Sun obtained in 1973 from the SKYLAB spacecraft. Most of the X-ray emission comes from loop-like structures tracing magnetic field lines. The dark elongated feature is a coronal hole (courtesy* American Science and Engineering).

boundaries of large convective cells where magnetic field lines are compressed by the fluid motions.

To give another example, Fig. 2 shows a photograph of the Sun obtained at X-ray wavelengths from onboard SKYLAB. Again, is apparent the highly structured nature of the corona which is formed by closed arch-shaped structures which apparently trace magnetic field lines. Only regions of low magnetic field intensity, where the lines of force are open to the interplanetary space, are devoid of dense coronal material and appear as dark features on X-ray photographs. Such regions, called for obvious reasons "coronal holes", are now known to be the source of high velocity wind streams flowing through the interplanetary space.

Further constraints on the heating mechanism have been provided by observations of wave motions in the solar transition region, as well as by stellar observations from the International Ultraviolet Explorer and the EINSTEIN Observatory. Solar observations of line broadenings and shifts from OSO-8 and the Solar Maximum Mission have shown evidence of the presence of acoustic waves in the transition region between the chromosphere and the corona. Unfortunately, the energy flux associated with the detected motions, although probably sufficient to heat the solar chromosphere, is too short by several orders of magnitude to heat the transition region and the corona.

At the same time stellar observations from IUE and the EINSTEIN Observatory have demonstrated the existence of transition regions and coronae for late-type stars of virtually all spectral types and luminosity classes (the only exceptions are late-type giants and supergiants with strong winds and large mass loss rates). This is in gross discrepancy with the acoustic theory which predicts that only stars of spectral type F and G should possess high temperature coronae. Early-type stars would be excluded by the absence of an appreciable outer convection zone, while coronal emission from K and M stars would be drastically reduced by the decrease of the convective velocity towards later spectral types and by the strong dependence (to the eighth power) of the acoustic energy flux on the convective velocity.

More significantly, X-ray and UV observations, as well as previous ground-based observations in the Ca II lines, have shown that a very broad range of chromospheric and coronal emission levels exist for stars of the same spectral type and luminosity class. This observational result indicates that other parameters in addition to effective temperature and gravity are relevant for the heating of stellar chromospheres and coronae. As discussed below, a fundamental parameter may be rotation, owing to the key role played by rotation in determining the degree of dynamo-generated magnetic activity at the star surface.

How can magnetic fields help to solve some of these difficulties? The simplest way is to add a magnetic field to the treatment of wave generation, propagation and dissipation in a star with a subphotospheric convection zone. For instance, magnetoacoustic slow-mode waves, which are generated much more efficiently in magnetic regions than simple acoustic waves, might be very good candidates for heating stellar chromospheres, as suggested by R. Stein and P. Ulmschneider. Slow-mode waves can explain the observed spatial inhomogeneity and temporal variability of the solar chromosphere, as well as different levels of chromospheric activity in stars with the same effective temperature and gravity. Different activity levels, in fact, may result from different fractions of the stellar surface covered by magnetic fields.

Magnetoacoustic slow-mode waves are essentially acoustic waves channelled by the magnetic field. Their inclusion, therefore, does not solve the problem of the low energy fluxes associated with the wave motions measured by OSO-8 and SMM. In the corona, it is necessary to invoke other types of waves, for instance Alfven waves, which have much longer damping lengths, or to attribute coronal heating to the dissipation of electric currents flowing in non-potential magnetic field configurations. Both Alfven waves and current dissipation require the presence in the corona of magnetic flux tubes, such as those observed in X-ray photographs of the Sun (Fig. 2), as well as the presence of a certain degree of surface turbulence at the loop footpoints to shake or twist the lines of force. If the fluid motions are fast enough, Alfven waves are generated; if on the contrary the flux tubes are twisted slowly a DC current is produced. The dissipation of Alfven waves and of electric currents in the corona is a complex problem, a detailed treatment of which is far beyond the limits of this paper. Research in this exciting field is being pursued quite actively by several groups of plasma and solar physicists.

The Role of Rotation

That rotation may be important in determining the degree of activity in late-type stars is not a novel concept. This suggestion was made early in the sixties as a result of extensive observations of Ca II emission and rotation carried out mainly by O.C. Wilson and R. Kraft. By observing a number of star clusters of different ages (Hyades, Pleiades, Coma) and by comparison with observations of field stars, a statistical relationship was discovered between stellar rotation, chromospheric Ca II K emission and age, in the sense that both stellar rotation and Ca II K emission decline with age in main-sequence stars. At the same time, it was pointed out that the "average" rotational velocity of stars drops precipitously at about the same spectral type (middle F) at which subphotospheric convection zones and chromospheric emission become prominent.

A quite convincing scenario was immediately put forward to explain these observations. Late-type stars which possess outer convection zones are able to develop chromospheres and coronae, by some mechanism related to the presence of convective motions (e.g. generation of acoustic or magnetoacoustic waves). Analogously with the Sun, these stars will also be subject to coronal expansion under the form of a stellar wind. The mass loss associated with the wind (of the order of 10^{-14} solar masses per year for the Sun) is far too small to have any appreciable effect on the evolution of the star. However, it may be an important source of angular momentum loss, because of the braking action of magnetic field lines carried along by the wind. Calculations for the Sun show that the characteristic time for angular momentum loss due to the outflowing of matter in the presence of magnetic fields is comparable to the life-time of a solar-type star on the main-sequence. This explains the rapid drop of the average rotational velocities of main-sequence stars at about spectral type F5, as well as the observed decline of rotation rate with age at each spectral type.

More difficult to understand is why Ca II emission should decrease with age. A possible clue is given once more by the solar analogy. We know that the intensity of Ca II emission in the Sun is proportional to the average intensity of the surface magnetic field. If this is true for stars in general, we should ask ourselves why stellar fields decline with age. The simplest explanation is that the magnetic field of a star is a remnant of the interstellar field which remained trapped in the star at the time of its formation. As the star gets older, magnetic energy may be gradually converted into thermal and mechanical energy which is eventually radiated away. It seems unlikely, however, that primordial magnetic fields may have survived resistive decay in the relatively long-lived stars of spectral type later than F. More likely, and the generally accepted view, is that magnetic fields in late-type stars are continually regenerated by an internal dynamo involving rotation and convection. This is the mechanism which is thought to be responsible for the cyclic emergence of sunspots at the surface of the Sun.

The interaction of rotation and convection in the Sun produces differential rotation, with equatorial zones moving faster than high latitude zones. The shear action of differential rotation on a "seed" poloidal magnetic field produces field amplification by the so-called ω-effect, and gives rise to a toroidal component which eventually emerges at the star surface by magnetic buoyancy. Cyclonic turbulence will in turn regenerate a poloidal field from the toroidal one (the α-effect) and the process will repeat itself in a cyclic pattern. Since both the ω- and α-effect depend linearly on the angular velocity of rotation, the efficiency of the process is higher for more rapidly rotating stars, and this may explain the observed higher level of chromospheric emission in young, more rapidly rotating stars.

There are a number of empirical facts which support this interpretation. First, there is the case of RS CVn stars which are detached binary systems with an extremely high degree of chromospheric and coronal activity. Of the two component stars, the more active one is usually a K subgiant, that is an evolved star. As the star gets older and moves out of the main sequence, its radius increases and its angular velocity decreases, owing to conservation of angular momentum. We would therefore expect a very low efficiency of dynamo action in these evolved stars. On the contrary, we observe a very high degree of activity. The explanation is that tidal interaction of the two components produces synchronism of orbital and rotational periods, thus strongly increasing the rotation rate of the two stars. The equatorial rotation rate of the K IV component in RS CVn systems is in fact of the order of several tens of kilometres per second, on average.

Another, possibly related, line of evidence is provided by the so-called BY Dra syndrome in certain dMe stars. As shown by B. Bopp and collaborators, the high degree of activity of these systems is probably due to rapid rotation. In most cases BY Dra stars are young: in a few cases, however, the same phenomenon appears to occur in old stars which are members of binary systems and in which rapid rotation is enforced by tidal interaction. To summarize, there are a number of observational facts and theoretical considerations which all indicate rotation to be important in determining the level of chromospheric and coronal activity in late-type stars, via the generation of magnetic fields by dynamo action and their subsequent stressing and dissipation of turbulent motions.

With the advent of space observations, particularly after the launch of IUE and the EINSTEIN Observatory, a number of studies have been carried out with the purpose of determining in a quantitative way the law of dependence of chromospheric and coronal emission on rotation. The aim was to use this information to obtain a better understanding of dynamo action and coronal magnetic heating in late-type stars. The results of one such study are shown in Fig. 3, which is a correlation diagram of X-ray luminosity (as observed by the EINSTEIN Observatory) and rotational velocity for stars of spectral type later than middle F. The plot shows a clear dependence of X-ray coronal emission on rotation, which in first approximation can be expressed by a quadratic law. The plot, however, shows also the presence of a large scatter around the average relationship, which makes it difficult to determine the exact functional form of the dependence as well as to ascertain the relevance of other parameters (for instance, spectral type or, equivalently, depth of the convection zone).

One of the difficulties encountered in making correlation diagrams such as the one shown in Fig. 3 is the lack of accurate determinations of rotation velocities for the vast majority of stars of spectral type G and K which rotate at rates less—often much less—than 10 km s^{-1}. Only recently high resolution spectroscopic determinations of very low rotational velocities have become possible, but the results are still scanty and virtually absent for southern stars. For this reason, M. Pakull of the Technische Universität in Berlin and myself started in 1982 a programme of high resolution observations of cool stars using the Coudé Echelle Spectrometer (CES) at ESO, with the purpose of measuring rotational velocities and

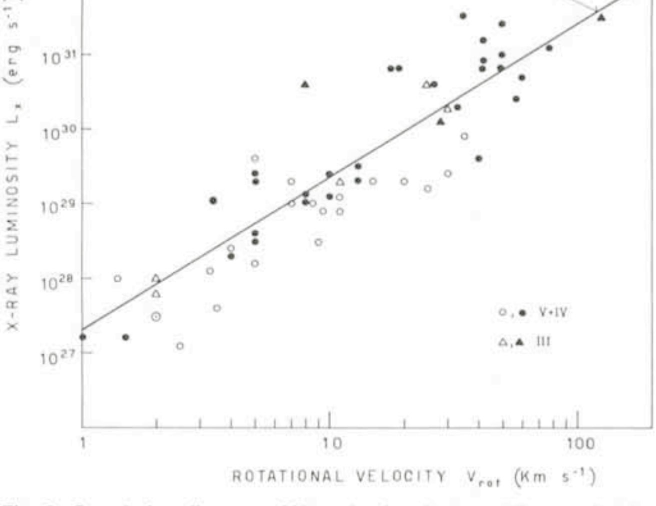

Fig. 3: *Correlation diagram of X-ray luminosity vs. stellar rotation for late-type stars as determined by the author on the basis of X-ray observations from the EINSTEIN satellite and available data on stellar rotation rates. Filled symbols refer to rotation rates inferred from photometric or orbital periods.*

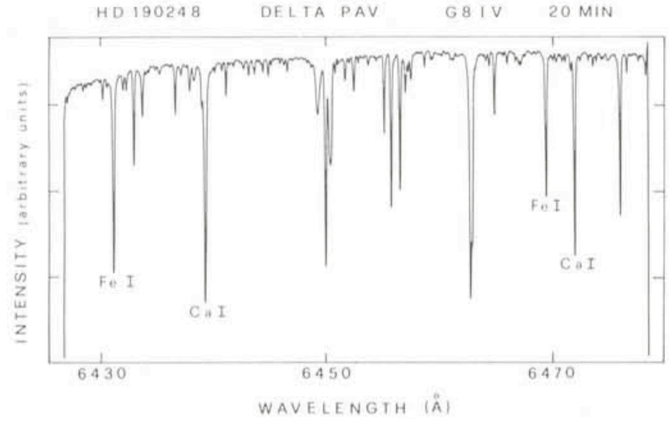

Fig. 4: *Quick-look spectrum of the G8IV star δ Pav at a central wavelength of 6450 Å obtained at La Silla on 18 July 1983 using the CES. Lines to be used for deriving rotational velocities with the technique referred to in the text are indicated.*

chromospheric Ca II K emission for a number of southern stars previously detected at X-ray wavelengths by the EINSTEIN Observatory. The preliminary results of this programme are summarized in the next two sections.

Measuring Rotational Velocities with the CES

The classical method of measuring stellar rotation is based on the broadening of photospheric absorption lines by the Doppler shift of the radiation emanating from the approaching and receding areas of the star. Application of this technique to stars of spectral type G or later, which rotate quite slowly, becomes increasingly difficult. Not only very high spectral resolutions are required, but what is more important is that other broadening mechanisms, such as micro- and macro-turbulence, become comparable to, and even larger than, rotation. An effective method for discriminating between different broadening mechanisms is mandatory. In practice, it is not convenient to use standard techniques for stars rotating at velocities lower than 10–15 km s^{-1} (we recall that the equatorial rotational rate of the Sun is only 2 km s^{-1}).

A suitable technique which has been suggested for measuring very low rotational velocities is the Fourier analysis of line profiles, which can be applied whenever the data are of sufficiently high quality. The basic principles of the method have been described by D. Gray in his standard monograph "Theory and Observation of Normal Stellar Photospheres", as well as in a number of subsequent papers scattered in the specialized literature. In practice, the observed profile is compared with a grid of computed profiles obtained by broadening a narrow absorption line profile derived from stellar model calculations. The broadened profiles are obtained taking into account the effects of rotation, microturbulence and macroturbulence. In order to discriminate between competing broadening mechanisms, the comparison is made in the Fourier domain, taking advantage of the fact that profiles broadened by different mechanisms have distinctly different Fourier transforms. Rotational rates of late-type stars obtained by this technique have recently been published by D. Gray, M. Smith, D. Soderblom and others.

An instrument which appears particularly suitable for this type of measurement is the Coudé Echelle Spectrometer (CES) recently installed at La Silla. We used this instrument fed from the 1.4 m Coudé Auxiliary Telescope (CAT) in two runs (3–9 December 1982, observer: M. Pakull; and 18–30 July 1983, observer: R. Pallavicini). The instrument was operated in the multi-channel mode with a 1,872 element Reticon detector. The high resolving power attainable, the very pure instrumental profile and the virtually absent scattered light are among the advantages offered by this instrument for the measurement of extremely low rotation rates of bright stars.

The observations were carried out in the red part of the spectrum at central wavelengths of 6020, 6250 and 6450 Å. In all cases the entrance slit was 200 micron corresponding to a resolving power $\lambda/\Delta\lambda$ of the order of 1.2×10^5. The spectral range covered at the above wavelengths was about 50 Å. The signal-to-noise ratio was in all cases greater than 100. We have observed more than 50 southern bright stars of spectral types F5 to K5 and luminosity classes III, IV and V.

Fig. 4 shows an example of the quick look data obtained at a central wavelength of 6450 Å for the subgiant star δ Pav (V = 3.6). The seeing was good and the integration time was 20 min. Fig. 5 shows the reduced normalized spectrum of 26 Aql (V = 5.01) at a central wavelength of 6250 Å. Typically, we have found that in average seeing conditions good spectra could be obtained in less than 1 hour integration time for stars brighter than V = 6.0.

The spectral regions chosen by us contain a number of unblended, intermediate-strength lines which are suitable for deriving projected rotational velocities v sini using Fourier techniques. Some of the lines to be modelled are indicated in Fig. 4. We are analysing these data in collaboration with D. Soderblom of the Harvard-Smithsonian Center for Astrophysics for main-sequence stars, and in collaboration with D. Gray of the University of Western Ontario for giants. Preliminary inspection of the data shows that most stars in our sample have extremely narrow lines indicating rotational velocities not substantially different from that of the Sun. Slow rotators, therefore, appear to dominate our sample of nearby stars, in spite of the fact that the latter was chosen mainly on the basis of X-ray observations. A few stars, however, have broadened lines which imply rotational velocities a factor 4 or 5 higher than for the Sun. When completely reduced, these data will be used in conjunction with previously determined X-ray fluxes to improve the correlation diagram of X-ray luminosity vs rotation shown in Fig. 3.

Measuring Ca II K Emission with the CES

During our observing runs at La Silla we have used the Coudé Echelle Spectrometer also for measuring Ca II K emission at 3933.7 Å, for the same stars observed in the red for rotation.

Observations in the violet with the CES + Reticon are much more difficult than in the red. The efficiency of the Reticon, which is about 70% at 6000 Å, drops to 30% at the K line. In addition, in our programme, we were observing late-type stars which are intrinsically fainter in the U band than in the V band,

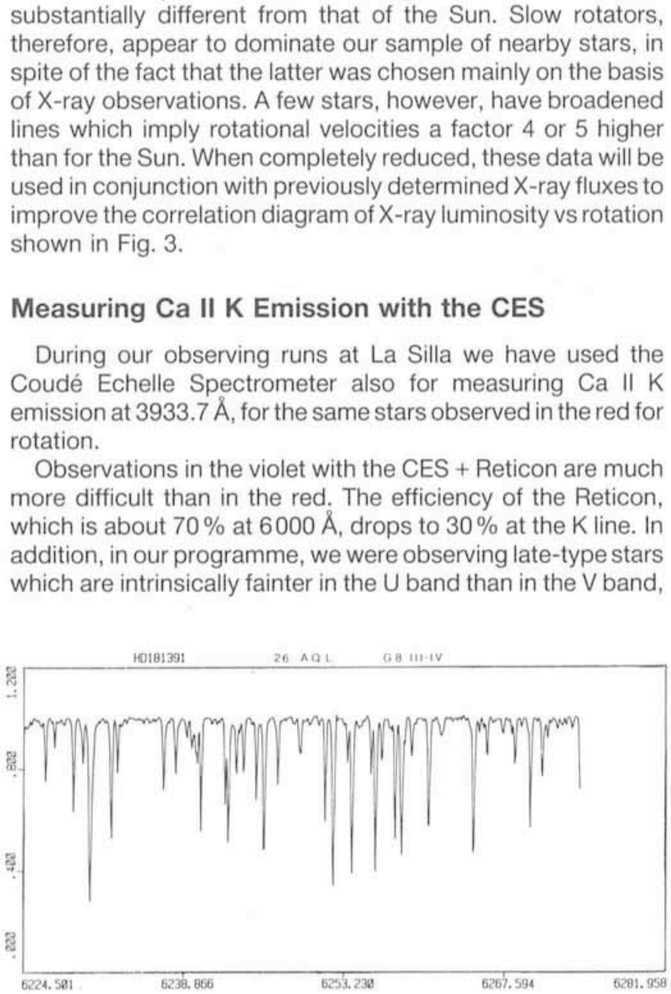

Fig. 5: *Reduced normalized spectrum of the G8III-IV star 26 Aql at a central wavelength of 6250 Å obtained on 19 July 1983 using the CES.*

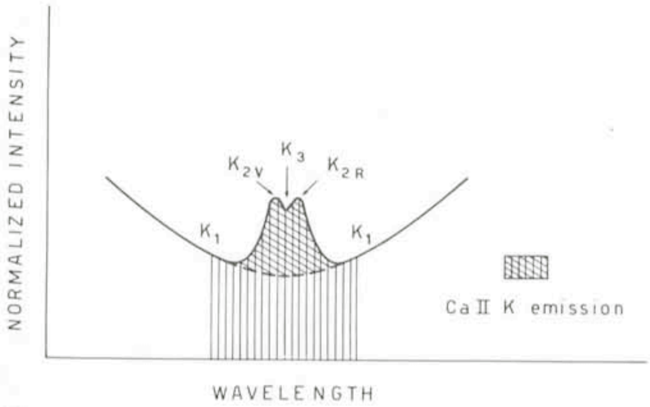

Fig. 6: *Schematic diagram of the central reversal in the K line of Ca II for active late-type stars.*

and, more importantly, we were interested in the—normally small—emission component at the bottom of a very deep absorption line. For all these reasons, observations in the violet turned out to be practical only for quite bright objects, and even so at the expenses of rather long integration times (usually of the order of a few hours).

The main motivation for our observations in the violet was to obtain accurate values of chromospheric Ca II emission fluxes calibrated in absolute units. It should be recalled that most observations made in the past were on a relative scale, which is not particularly suitable for discussing problems of energy balance and dissipation in stellar chromospheres. This is particularly true for southern stars, for which this information is virtually absent. Observations with the CES allow the simultaneous recording of a $\simeq 30$ Å band at the K line, which may be centred in such a way as to contain the emission reversal as well as the nearby pseudo-continuum at 3950 Å. From these observations, we can derive absolute fluxes in the emission component by using for instance the photoelectric calibration of the continuum spectrum at 3950 Å obtained a few years ago by S. Catalano of the Catania Astrophysical Observatory.

Another correction must be made to the derived equivalent width of the central emission component. Fig. 6 shows a schematic diagram of the central part of the K line in a late-type star. The central emission reversal K is superimposed on an underlying photospheric contribution which is indicated in Fig. 6 by the dashed line obtained by extrapolating the inner absorption wings to the line centre. In order to obtain a correct estimate of chromospheric energy losses in the K line it is necessary to subtract the photospheric contribution, either empirically by extrapolating the inner wings to the line centre, or better still by subtracting a photospheric contribution computed on the basis of radiative equilibrium model atmospheres. This correction may be quite strong for stars of spectral type F and early G and may be an important source of error in deriving chromospheric radiative losses for these stars.

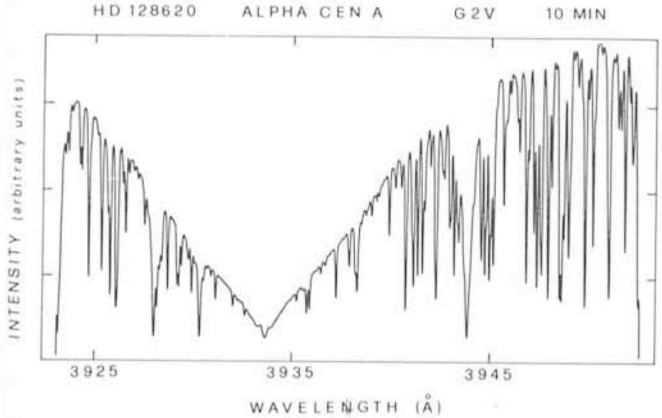

Fig. 7: *Quick-look spectrum of the G2V star α Cen A in the K line of Ca II obtained on 28 July 1983 using the CES. A quite similar spectrum is obtained when observing solar radiation reflected from the Moon.*

We have observed about 40 stars in the K line of Ca II. For very bright objects such as α Cen A and α Cen B we have been able to obtain high resolution spectra ($\lambda/\Delta\lambda \simeq 10^5$) using reasonably short exposure times. For all the other stars, we have used a somewhat reduced resolving power, ranging from 3×10^4 to 6×10^4, and typical exposure times from 1 to 4 hours. Even in the worst case, however, the spectral resolution is $\simeq 120$ mÅ, more than adequate to resolve structures in the central emission component.

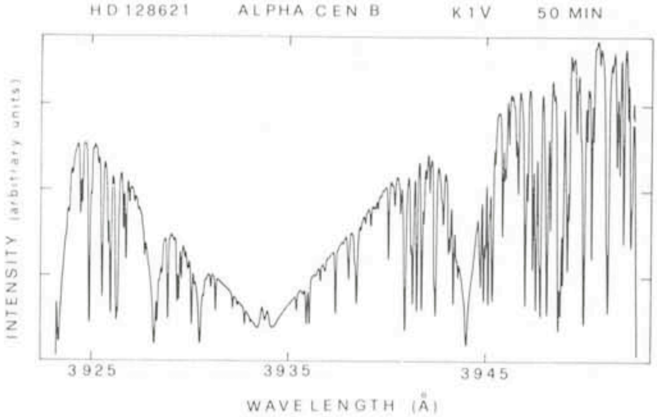

Fig. 8: *Quick-look spectrum of the K1V star α Cen B in the K line of Ca II obtained on 28 July 1983 at La Silla.*

Figs. 7 and 8 show high resolution quick look spectra of α Cen A and B. The G2V star α Cen A shows a barely visible emission component, similar to that appearing in integrated spectra of the Sun (obtained by looking at the reflected light from the Moon). The spectrum of the K1V star α Cen B, on the contrary, shows quite clearly the central reversal. It is interesting to note, however, that the energy flux in the K line is approximately equal for the two stars, stressing the importance of obtaining spectra calibrated in absolute units. The fact that the central reversal is much more easily seen in α Cen B is simply due to the fact that the underlying photospheric background is much reduced, thus allowing the chromosphere to shine out more clearly by contrast.

Fig. 9 shows the reduced spectrum of the central part of the K line in the K5V star ε Ind ($V = 4.7$). Notice the very strong central reversal, which indicates a degree of chromospheric activity higher than the one typical of stars of the same spectral type. Fig. 10 shows the combined spectrum of the visual binary system 53 Aqr A + B obtained in a 4-hour exposure. Since the two component stars are quite faint for observations with the CES in the violet ($V = 6.3$ and $V = 6.6$, respectively) we have used a rather wide slit (1,000 mÅ) collecting light from both stars simultaneously. We know from an old photographic spectrum published in 1965 by G. Herbig that the intensity of the central reversal is approximately the same for the two components. Although their spectral types (G1V and G2V) are about the same as for the Sun and α Cen A, their chromo-

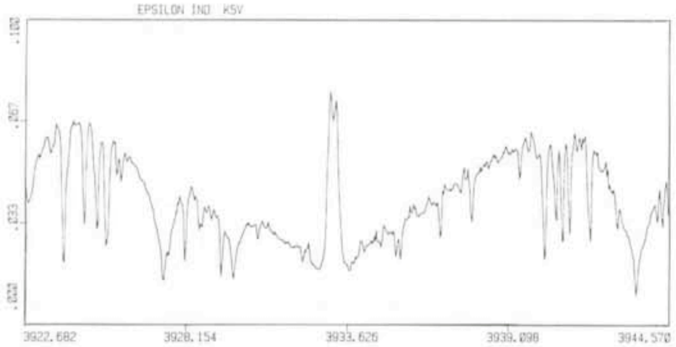

Fig. 9: *Reduced spectrum of the K5V star ε Ind in the K line of Ca II obtained on 27 July 1983 using the CES. Notice the strong central reversal.*

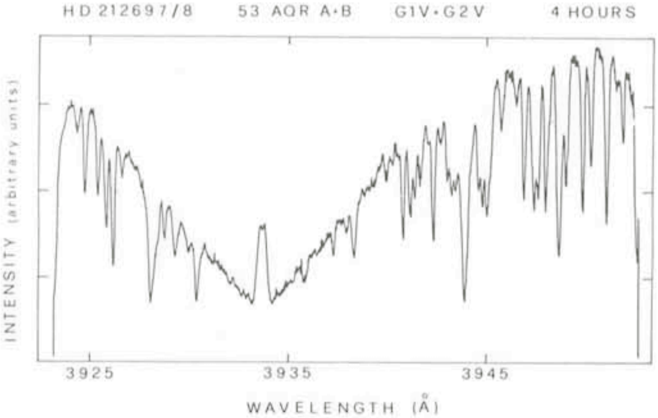

Fig. 10: *Combined spectrum of the visual binary system 53 Aqr A+B in the K line of Ca II obtained on 29 July 1983 using the CES. The chromospheric emission reversal from these young rapidly rotating G1V+G2V stars is much higher than for α Cen A or the Sun.*

spheric emission is strongly enhanced with respect to the average Sun or α Cen A. In fact, it is more similar to that emitted by plage regions on the Sun. This is in agreement with the relatively high rotation rate of the two stars, which is a factor 4 higher than for the Sun. This system was not pointed at by the EINSTEIN Observatory. Observations at X-ray and UV wavelengths from IUE and EXOSAT are planned for 1984 as part of the authors's Guest Investigator programmes on these satellites.

I would like to conclude by emphasizing the importance of obtaining, preferably simultaneously, accurate values of chromospheric and coronal radiative losses for stars of different spectral types and degree of activity. It is not clear at present, even in the case of the Sun, whether the same mechanism is responsible for heating chromospheres as well as coronae. Although magnetic fields appear to be fundamental in both cases, their role in the heating problem may be different at different levels in a stellar atmosphere. It is quite conceivable, on the basis of the available evidence, that magnetoacoustic slow-mode waves may be the main process of non-thermal energy deposition at chromospheric levels, while Alfven waves and possibly current dissipation are probably needed at coronal heights. A correlation diagram of coronal X-ray fluxes vs chromospheric Ca II K fluxes may provide insights into the problem of chromospheric and coronal heating, provided one has some additional information on the ratio of Ca II K losses to total chromospheric radiative losses for stars of different spectral types. Observations made with the CES at La Silla, although somewhat limited by the present difficulty of observing faint objects at short wavelengths, may be instrumental in providing the necessary data basis for such studies.

Acknowledgements

It is a pleasure to acknowledge the cooperation of M. Pakull in the acquisition, analysis and interpretation of the ESO observations, as well as for enlightening discussions related to the subject of this paper.

List of Preprints Published at ESO Scientific Group

December 1983—February 1984

299. F. Caputo, V. Castellani and M. L. Quarta: A Self-consistent Approach to the Age of Globular Cluster M15. *Astronomy and Astrophysics.* December 1983.
300. C. Cacciari, V. Caloi, V. Castellani and F. Fusi Pecci: IUE Observations of UV Bright Stars in Globular Clusters M15 and wCen. *Astronomy and Astrophysics.* December 1983.
301. V. Caloi, V. Castellani, D. Galluccio and W. Wamsteker: Far Ultraviolet Spectra of the Nuclei of Globular Clusters M30, M54, M70. *Astronomy and Astrophysics.* December 1983.
302. F. Caputo, V. Castellani, R. di Gregorio and A. Tornambé: Theoretical RR Lyrae Pulsators from Synthetic Horizontal Branches. *Astronomy and Astrophysics.* December 1983.
303. S. Cristiani, M.-P. Véron and P. Véron: On the Completeness of the Braccesi Deep Quasar Survey. *Astronomy and Astrophysics.* December 1983.
304. M. Rosa, M. Joubert and P. Benvenuti: IUE Spectra of Extragalactic H II Regions. I. The Catalogue and the Atlas. *Astronomy and Astrophysics.* December 1983.
305. J. Krautter, B. Reipurth and W. Eichendorf: Spectrophotometry of Southern Herbig-Haro and Related Objects. *Astronomy and Astrophysics.* January 1984.
306. M. Iye: Oscillations of Rotating Polytropic Gas Disks. *Monthly Notices of the Royal Astronomical Society.* January 1984.
307. D. Baade and R. Ferlet: Discovery of a Possibly Rotation-induced Resonant Coupling of two Nonradial Pulsation Modes in γ Arae (BIIb). *Astronomy and Astrophysics.* January 1984.
308. M.-H. Ulrich and D. L. Meier: 5 GHz Observations of Cores in Extended Radio Galaxies. *Astronomical Journal.* January 1984.
309. M. Mayor et al.: Studies of Dynamical Properties of Globular Clusters. I. Kinematic Parameters and Binary Frequency in 47 Tucanae. *Astronomy and Astrophysics.* January 1984.
310. T. Ueda, M. Noguchi, M. Iye and S. Aoki: Global Modal Analysis of Disk Galaxies: Application to an SO Galaxy NGC 3115. *Astrophysical Journal.* January 1984.
311. D. Gillet and J.-P. J. Lafon: On Radiative Shocks in Atomic and Molecular Stellar Atmospheres. II. The Precursor Structure. *Astronomy and Astrophysics.* February 1984.
312. O.-G. Richter: Redshifts in Klemola 27. *Astronomy and Astrophysics, Supplement Series.* February 1984.
313. D. R. Jiang, C. Perrier and P. Léna: NGC 2024 # 2: Infrared Speckle Interferometry and Nature of the Source. *Astronomy and Astrophysics.* February 1984.
314. W. K. Huchtmeier and O.-G. Richter: HI Observations of Isolated Spiral Galaxies. *Astronomy and Astrophysics.* February 1984.