THE ACTIVE SUN AS A STAR ......

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I have the great honour of being the first speaker from abroad. It gives me the pleasure of expressing to our japanese colleagues our deepest thanks for their warm hospitality this week and for the permanent stimulation which is given, to their french colleagues, by the various cooperative programs in the making, at the solar telescopes, or behind the computers, or again in the midst of the equations. In particular, I would like to express my gratitude to Professor Zenzaburo Suemoto, to whom solar physics owes so much, and I would like to recall that we met for the first time more than thirty years ago, at the Institut d'Astrophysique ... Solar Physics has indeed always been a very friendly science, all over the world. I would like also to express our deep thanks to Professor Moriyama, Head of the Solar Division of the Tokyo Observatory in Mitaka, and to Professor Unno, who contributed both so efficiently to build up the program of this meeting, and we know that it has not been always easy, especially to find suitable dates; and I must apologize to them for the many constraints that the french side has perhaps put on this meeting ... Finally I would like to thank all members of the Tokyo Observatory and of all other Japanese Institutions, who are present here, amongst whom we have many old-time friends and colleagues, and who are making so much now to make our stay scientifically efficient, and most pleasant on the purely human side. Japan is a great country, full of beauties, rich of its past, and of its future. We are very glad to be here ... Thank you very much indeed. Dom Aligato !

Japan is in particular the country of the morning sun, rising on the eastern horizon, above the Pacific ocean. May this symbol guide the spirit of our meetings ...

For a very long time indeed, it was not even conceived that one could ever compare the Sun, a large luminary rising in the morning, setting in the evening, and following a rather complicated network of apparent motions around the observer, and those stars, fixed with respect to each other, and defining a reference frame for the solar motion and not much else. A very early attempt to determine the size of stars, from their "apparent diameter" (which was not yet identified with an artifact of the eye or of the instrument), and from their minimum distance, (assuming that it was necessary to explain they had not any observable annual parallax, as a consequence of the copernician description), gave diameters at least thousands of times bigger than that of the Sun ... This was a disappointment, which led Tycho Brahé to even doubt the copernician system ...

The first one to decide that stars may after all be other suns, was Giordano Bruno, and he was burned for that in 1600. Galileo discovered stars in the Milky Way, but he did not, explicitely at least, admit a parenty between these very weak bright points and the Sun ... Fontenelle, in his "Discours sur la Pluralité des Mondes", and the newtonian school, went along the line of Bruno; but the similarity between Sun and stars became obvious only at the time of the first true distance determinations (which enabled us to compare the absolute brightness of the Sun with that of the stars) made by Bessel in Germany, Henderson at the Cape, and Wilhelm von Struve in Russia. -in the late eighteen-forties; at the time of the first radius determination, by Vogel in 1888, of Algol, an eclipsing binary; and at the time of the first stellar line spectra, obtained by Huggins, at about the same time, in the years 1860 ...

To make a long story short, the stars were, undoubtedly, similar in nature, size, etc... to the already rather well-known Sun. The stars were suns ... That was indeed the main conclusion of the XIXth century.

The enormous flow of observations, which gave place to the bulk of stellar classification, and the theoretical studies of gaseous spheres in equilibrium conditions, gave both a great coherence to the description of the many families of the stellar world; the calibration in size, mass, temperature, of the various types or classes of stars had achieved in the XXth century, a state of completedness, which was, in spite of a few drawbacks on which I shall not comment today (see Pecker, 1973), rather remarkable.

Hence several authors started to ask one first question; if the Sun were, say, at a distance of 10 parsecs, what would be its classification as a star, what would be its "stellar" properties ? Many papers appear as typical of this attitude, which was a conscious attempt to calibrate better the stellar sequence by the use of the solar well-established properties. It was then decided that the Sun was a star of type G 2, of luminosity class V. Amongst these many papers, I would like to quote, as an epoch-making one, the chapter written by Bengt Strömgren, in 1952, in Kuiper's "The Sun", under the title "The Sun as a Star". There, the internal structure is sketched, the extent of the convection zone estimated to 200000 km. But boundaries are hardly described by anything else but the value of the effective temperature, and the vanishing of density and pressure. An outline of solar evolution was also described, in a rather promising way. Tons of papers, after that paper, have been devoted to "the Sun as a star", even when this was not the exact title of the paper. In most of the cases, authors did present elaborated views on solar and stellar structure and evolution, and went as far as deducing, from the solar photospheric properties, some necessary properties of the stars and as searching for them. We could for example quote the systematic look at eclipsing binaries for limb darkening data; or the study, from the spectrum, continuous, and lines, of the physical stratification of the photospheric layers. But the recent improvements in photometric accuracy have opened a new field : we measure minute variations of the solar constant, due to the rotation (and disappearance behind limb) of spots; we measure variations on the solar disk of K_{23} emission and can detect stellar plages.

In another line of thought, the fact that the Sun is variable, at least over some parts of his surface, with time, has led to a solar-like nomenclature : one has been speaking of spotted stars, of flare stars, of active stars. But the claimed analogy could be highly misleading, as it was, indeed, quite superficial, and did not imply any physical resemblance ... How indeed could it otherwise be ? The fine structure of the Sun is non-observable on stars ! I think about the granulation, the active features, spots or prominences, or the flares; moreover, the time resolution of the instruments is not at all of the same order of magnitude; no stellar eclipse is sufficiently comparable to solar eclipses to let the observer guess the temperature rise in the chromosphere and corona; all of this was, more and less, induced from theoretical reasonning, inasmuch as one knew something, not always very much, about the mechanisms of the solar phenomena.

As solar physicists, with the blooming of space research, got more and more interested in chromospheric and coronal events, in the solar wind, in the magnetic features, -the stellar physicists did not realize at first how these new and rapidly growing fields of research could be of some interest to them. However, some astrophysicists -and you must pardon me if I quote now a paper by Thomas and myself (1976)- advocated strongly the fact that the Sun, irrespective of its spectral classification, more or less irrelevant because of its simplicity, the Sun as it is, with all its complexity, was indeed a sort of microcosm, a stellar laboratory; there all sorts of phenomena, that could be very large and intense in some stars, could be easy to study on a moderate scale, even very moderate, and allow a much better understanding of similar stellar phenomena, that appear often, in the stellar context, as gigantic or even cataclysmic.

The study of solar-like GK m.s.-stars is now indeed filling the gap, and allows us to feel more confident, or perhaps to reject what initially was only an analogy.

Putting the active Sun as the center of our analogic study, means, essentially, that we feel that we are concerned with an effort for a better angular resolution, now conceivable for stars, with an effort for a better time resolution also, allowing to detect very rapidly variable phenomena, and, evidently, with an effort for a better spectral coverage, allowing now to reach chromospheric and coronal layers through X and UV spectra.

Clearly, in the coming days, we shall cover only a few questions, dealing with what we can realistically study, being what we are, having the instruments we have, and limited by our budgets; we shall concentrate mostly on active features of short and long duration, and on their understanding. But we must keep in mind that several aspects, about which we shall not speak, of the "solar activity", may be later discovered in stars, or even are already known in them, and that their knowledge may perhaps, in some occasions, illuminate what we are able to study in the solar features; and the reverse is still more true.

And, at this point, we should probably remember, as a guide line, a comment made, I believe, by Cecilia Payne-Gaposhkin, who said, after looking at the first UV spectrum of the Sun, obtained by Tousey and others : "Well, well .. But this is a typical Wolf-Rayet star !..".

Indeed, to me, the "active Sun" is the ensemble of solar features which are variable with time, -at any scale of time, -and which rarely affect the whole of the solar surface; it is also, accordingly, the ensemble of solar features which occupy a definite part of this surface, large, as the supergranular cells, or small, as the spots, the flares, or even the granules ... Everything which departs from a gaseous sphere, spherically symmetric, in equilibrium, and stationary, i.e. from the traditional model of an ordinary star, is indeed what we are concerned with.

In introducing our debate, I shall be obliged, I feel, to bypass its scope, which had to be kept realistic ... I shall try to give a few examples of solar phenomena which have their analog in the field of stellar studies, or vice-versa. I hope you will pardon me if this quick coverage is neither exhaustive, nor very deep, and if my few examples are covered rather superficially. As I told the study of solar-like stars, now feasible, may alter somewhat the quality of some of the possible analogies.

I shall follow more or less the natural trend of progress in our understanding, starting from phenomena which are very general, such as the chromospheres and coronae, the phenomena which are not closely linked to magnetic fields, such as pulsations, winds; .. and finally, the magnetic phenomena, spots or flares, in their optical manifestations; ending by considerations on stellar magnetism and stellar cyclic activity.

1. The solar and stellar chromospheric and coronal features

The solar spectrum is much more sensitive in the XUV, and in the radiowaves, to the active phenomena, as the latter influence strongly the chromospheric and coronal radiation, which in their turn, mark definitely the XUV and radio spectra, whenever the visible spectrum is hardly affected, except in the cores of some emission lines.

From spectra alone, the extension towards the short wave-lengths and the fine resolution of the spectra obtained using scanners or photon counters, gave already much more than the classical picture of equilibrium photospheres.

The non-LTE effects, even in photospheres, were obvious from studies pursued along the main sequence. Let us only recall the work by Mihalas, where he showed beyond doubt that the behaviour of the magnesium lines could not be explained with a single value of the abundance, but only by taking into account a proper non-LTE treatment, whenever it was thought necessary, before his important papers, to admit that the magnesium abundance was varying along the main sequence, from a value of $4 10^{-5}$ in the solar case, to a value of 10^{-3}-10^{-4} in the case of OB stars.

The existence of chromospheres was first inferred from the feeling of their necessity : the early theories of the chromospheric heating led to consider that a chromosphere should appear in stars were an hydrogen and/or helium ionisation convective zone was present near the surface. Hence people expected chromospheric features to appear in the spectrum of many stars of type later than A but not earlier. Truly enough, some emission features were known, but mostly in rather exceptional cases. But, the space-gathered spectra have later shown, indeed, that the heating of a chromosphere is quite a general phenomenon and a variable one which concerns the whole of the spectral sequence : and this shows at least that one should come back with a new eye on the theory of solar chromospheric heating; it shows also that if hints can be obtained from solar studies, none of the solar studies are final, -and the benefit is mutual.

Quite typical of a stellar chromospheric phenomenon, and, moreover, of a law which can relate chromospheric properties to overall stellar properties is the well-known Wilson-Bappu (WP) effect. I have not, I presume, to recall the essential features of the relation which seems to associate, in a one variable dependance, the absolute magnitude Mv to Wo, the full width at half maximum of emission cores of ionized calcium H and K lines. It may be interesting however to note that this effect was indeed discovered more than fifty years ago by the solar physicists, Deslandres and Burson, working in Meudon.

Similar effects, i.e. one-variable correlations, have been found in the cores of other intense lines, -such as Lyα , or MgII doublet. Wings of H and K obey also relations of the same type.

It is remarkable to note that the WB effect concerns a very large range of magnitudes (more than ten magnitudes). The role of other parameters have been looked for : the metallicity indices seem not to influence the line width;neither is it correlated with the importance of the emission, which possibly measures the depth of the chromosphere, whenever its width measures the non-thermal velocity fields.

There is no need of much thinking to say that the study of the cores of these lines, in the solar spectrum, may enable us to understand better their formation, in active regions notably, and hence to infer some interesting interpretation of the stellar chromospheric data. We shall speak certainly of our solar results in the following days.

One normal approach to the problem is theoretical; one has to build up a good theory of the formation of H and K lines, vary the parameters, play with the models, the abundances, the velocity fields, the geometry, etc... The other one is statistical. If one judges the respective advantages of both methods from their results, it is clear that the first one has not been as satisfactory as one might have thought; since the earlier researches by Miyamoto, in the late forties, much progress of course has been accomplished, but not enough, in the sense that one does not yet describe properly the velocity fields in the chromospheric layers. So why not to try also the statistical approach, from the stellar view point, in order to understand better what parameters do in fact influence more the K and H profiles ? The recent study of 60 G stars I earlier mentionned goes into that direction.

The study of chromospheric features in the spectrum of faculae, in this respect, can be considered both ways. Either we could start from model techniques, to have realistic hints about the differences between quiet Sun physical parameters, and facular physical parameters, explaining, by the differences in these parameters, the differences between facular and quiet-sun H and K lines, and compare them also with the stellar cases, in order to select those which are really significant, and to build a better facular model. Strange behaviours (as shown by Dumont et al, 1980) indicate a strange boundary behaviour of turbulence, -a phenomenon not likely to affect the spectrum of the star as a whole, hence significant physically, but not observable on stars ...

Time sequence were obtained of stellar chromospheric features. They concern of course first the visible spectrum, and in it the center cores of some emission lines. The case of Be stars is quite typical in this respect. A star like 50 Cygni displays variable Balmer lines, showing at the scale of minutes or hours, or at much larger scale, marked changes in the chromospheric structures. (Doazan et al.). It is remarkable to note that several stars appear as Be some times, as normal B at other phases; a 3-phase description can be done (Be, B shell, B norm.).

Many such observations are now piling, once the attention has been drawn upon them. Let us quote the increase by a factor 3 of 01 8446 in V 1016 Cyg between 1979 and 1980, the appearance of He II 10123 in HM Sge with a great intensity; an increase of a factor 2 of OI 8446 in MWC 349 A during the same period, -most of the other emission lines being unchanged during the same period ...

Emission features from high excitation, high ionization lines, are chromospheric indicators; they are in general, as on the solar surface, highly variable.

The existence of coronae proceeded from the same type of information. Lines of various ions, of an high degree of ionization, have been observed in the stellar spectra. And more recently, the Einstein discoveries -I mean the Einstein satelli-- have shown that many stars were indeed surrounded by hot coronas, whatever their type, whatever their character of either double close binaries or detached stars ...

The Einstein satellite has been so sensitive as to bring the proof of existence of coronae, in ordinary stars, with X-ray luminosity ranging from 10^{26} to 10^{34} ergs per second. Young O, B, A stars, as well as late K and M stars, have coronae producing X-ray fluxes of 1000 to 1 million stronger than expected.

The dispersion of the diagramm, build for main sequence, F_X/F_V as a function of spectral type shows that the heating mechanisms depends upon (at least) a new parameter, to add to the classical T_{eff} -g Hertzprung-Russell theoretical coordinates.

The X ray-Sun is well known. The case of the binary Alpha Centauri is also typical : the K star has a bright corona; the G star has a weak one, -contrary to some theoretical expectations inspired by solar theories. We should note it is not a close binary; hence X-ray emission is not associated, as in many other well-known cases, to the stellar duplicity.

One should also mention, as important in this respect, the discovery of strong X-ray stellar bursts, perhaps similar to radio solar bursts. These objects have seemingly a very high absolute X-ray luminosity, of 10^{37} (or more) ergs per second, and the flashes increase that luminosity by a factor of 10 to 1000.

Along the same line, P-Cygni-like profiles, indicative, in general, of rather noticeable mass loss, have a variable behaviour, proving indeed the modulation of the stellar wind by the fluctuations of coronal activity. Variations in X-rays of some stars led to similar conclusions, as shown for instance by Matsuoka and his associates at the Uchinoura station, using Makucho X-ray satellite.

They, for example (Inue et al.), find the emission line of O VII, at 0.57 keV (or 22 Å) in agreement with a temperature of the order of a million degrees K, in the X-ray spectrum of some large region, possibly interstellar -but is not there the heating mechanism similar to those of coronae ? X-ray flares are of course indicative of some coronal transients. We shall come back on them.

From that kind of studies, we can deduce that the stellar radio spectrum should also be indicative of coronae, and through coronae, of coronal activity, of stellar activity. Too little at this time is known on stellar radio spectrum, at least to my very limited knowledge, to enable me to comment on the radiastronomical side of the question. However, it is clear that radio data would be tremendously valuable; they would allow to distinguish between the different parts of the corona, because of the different behaviour of the Rayleigh-Jeans law in the radio waves, and of the Planck's law in the XUV.

One general conclusion we can draw, at first, from the bulk of these studies, of which I have only quoted some examples, is that chromospheres and coronae are a general phenomenon; and, as such, it is impossible to link their existence with that of the hydrogen-helium convection zones.Hence some other mechanism has to be found, in order to explain the heating of these outer layers, even in the case of Sun.

Recent studies by N. Mein have proved, beyond doubt, I think, the purely mechanical wave dissipation to be totally inadequate. May be the magnetic waves or hydromagnetic waves dissipation may play an important role. Hence, for the sake of solar-stellar physics, we have got to ask one question : what are the parameters, -outside T_{eff}, g and the chemical composition, -which really command the source, inside the star, of the heating mechanism ?

Asking such a question is imperative; and one single additional parameter may not be sufficient, as seen from the distribution of X-ray flux in the HR diagramm.

2. The pulsating sun and pulsating stars

For years, pulsating stars, cepheids for example, have been known. But nothing was even suspected on the solar oscillations.

Nowadays, we know much about them; and the theory of vibrational instabilities and wave propagation has bloomed indeed, bringing much to both solar and stellar studies.

On the solar side, the first detection of oscillations was that of Leighton, Noyes and Simon, 1960, and very soon after, by a different technique, that of Evans and Michard. At that time, the evidence was pointing out to oscillations of five-minute period or so. They were clearly affecting the photosphere, in a more or less coherent way. The amplitude of the velocity modulation is of the order of 0.5 km sec^{-1} (r.m.s). In the photosphere they propagate at a velocity of 6 km s^{-1}.

Further studies (such as by Fossat and Grec) of the 5-minutes oscillations have shown them to be of a rather complex nature. They are standing acoustic waves, trapped near the solar surface in a 10000 km deep layer. The fundamental mode did not carry as much energy as the highest harmonics, found to have rather high n values, -being understood that one can distinguish radial modes, -denoted by n- and surface modes, -denoted by l, and m, -the analogs of the atomic quantum numbers.

Measurements during large periods of time, and of a sufficiently large part of the solar surface, helped to discover in the traditional time frequency-space frequency diagramm, -the ω-k. diagramm- a fine structure, or even a sort of hyperfine structure.

What is the nature of these waves ?

One should at this stage recall the study made of the restoring forces. In the ω-k diagramm, the regions of the diagramm differ mostly by the kind of restoring force which acts the more efficiently. They can be compressibility (giving place to pressure waves), or the gravity (gravity waves). The first is acting in a compressible medium, even in absence of gravity; the other acts in a hydrostatically stable medium, even in the absence of compressibility of the medium (for example, the Archimedes forces).

Without entering here into the well-known details of the theory, one can clearly show that the 5-minutes oscillations are identified as sound standing waves formed in a cavity between the top of convective zone and the bottom of the chromosphere, not far from the temperature minimum. They have a damping time of about 600 periods, or 1 day 1/2. We shall of course refer the reader to more extensive papers on the question such as those by Leibacher and Stein, by Ando and Osaki etc...

Another type of pressure mode oscillations, of about 3 minutes period, is associated with the trapping in the chromosphere; they have been observed with OSO 8, in an extensive way, by French and American groups and correspond to a cavity above the chromosphere.

Another type of waves, note easy to interpret completely,and associated with oscillations of the Sun as a whole, have been recently found by several groups of observers, firstly by Severny, Kotov and their associates, with a period of 2 h 40 mn. These oscillations, detected from radial velocity measurements, are visible also in solar diameter measurements made by Hill and associates. They seem to be low order gravity modes which penetrate entirely the convective zone, and are observable. Their existence, questioned for some time, is now established beyond doubt by the very observers who expressed the doubts the more seriously, Fossat and Grec, in Nice. They observed from the exact location of South Pole, during several no-stop sequences including one of 120 hours in a row, and, being so located, ruled out definitely any interpretation by a modulation due to terrestrial influence (2 h 40 mn being exactly 1/9 of a day). Moreover, the phase (assuming a period of exactly 2 h 40 mn) has been changing during the few years of observations, and the observers now agree with the value of 2 h 40 mn 1 s $\pm$ 0.1 s. for these oscillations; the amplitude is very small, of only 4 m s^{-1}. They correspond to a low radial n-order. Why is this isolated frequency alone, without harmonics ? A coupling with the high precision clock which solar rotation is, has been advocated.

Oscillations being observed on the whole solar disk, one is tempted to think about pulsating stars, just in the same way as about the pulsating Sun. The theory has been elaborated, due to the extent of solar studies, so much, that predictions could possibly be done in a near future in stellar cases. Observations of cepheids have mostly revealed radial pulsation internal gravity modes, of low order numbers. Not only the fundamental mode, but its harmonics, have often been observed. A good example is that of the β Cephei stars, another one that of γ Scuti variables. It is difficult to give here a complete survey and many other examples should be given.

We can quote also a recent example of non-radial modes observed by Myron Smith in the case of 53 Per. This star, of type O 4.5 V, displayed, in 1976-77, retrograde oscillations of periods 4.5 and 9.0 hours, in 1978 oscillations of 14.1 and 22.9 hrs in the prograde sense, through studies of line Si III 4552. Other stars (10 Lac, 22 Ori, ι Her, -of types OB-IV, V) seem to have a comparable behaviour.

Direct diameter oscillations are still out of the possibilities of stellar observers; but the possibilities of speckle interferometry and arrays of telescopes are still quite open, and might progress considerably. On the other hand, solar physics could progress from the study of cepheids and other variables. We should remenber that the oscillations theory, has made much benefit out of the good early studies of the propagation of waves in oscillating cepheids.

3. Solar and stellar winds

The existence of the solar wind, between the Sun and the Earth, and beyond the Earth, is a rather well-known phenomenon. We know it through cometary tails studies, and through many spacecraft measurements at distances to the sun varying form less than 0.5 UA to several UA. Its basic properties are its variability and the fact that its characteristics can be explained by assuming large sectors of definite magnetic polarity from the solar photosphere throughout the solar environment.

Stellar winds, on the other side, are detected only through spectral characteristics, essentially through P Cygni profiles.

It is however possible (for example in the Rosette nebula or in the Trifid) to see cometary -like features, undoubtedly due to some kind of expansion or wind; but they teach us rather little on the properties of the wind.

The wind is essentially defined at a given time, and at a given point on the star by its flux of mass and by its velocity; altogether, the average velocity and the integrated loss are parameters which might be helpful to know. Clearly enough, there is not much correlation between these two parameters and the classical two parameters on the HR theoretical diagramm. Only can be found a very vague indication that mass loss is more important for stars of high luminosity, cold or hot. Clearly, winds are associated with a rather slow decrease of density outwards (up to a decrease in r^{-2}), and this may be the origin of rather dense or thick chromospheres and coronae.

The winds are essentially variable, as can be easily and frequently observed in the UV or visible spectra of many O-B stars.

A difficult point is brought up by the question of gas accretion by hot OB stars. It can be shown that the collapse time of a pre main-sequence massive star is longer than the duration of its stay on the main sequence; in other terms, the protostellar cloud is still infalling, whenever the star is already formed and even evolved; and we do often observe winds ... How can these facts be compatible ? We should remember that rotation of the OB stars is rapid; hence the accretion may be polar, whenever the wind may be more or less equatorial ... It would be of a great interest to look at this question around the Sun : the existence of the solar wind does not necessarily exclude a certain amount of accretion, perhaps polar, in spite of the (small) rotational velocity of the Sun.

4. The solar and stellar surface spottedness

Variations in the spectrum, i.e. indicators of cinematical and physical variations in the outer layers, this is one aspect of the stellar activity, allowing to detect pulsations and winds ...

Another one is the spottedness of the active regions. For a long time, since the earlier works of Armin Deutsch, I believe, one thought that the irregular distribution of physical properties on the surface of stars could explain periodical changes, with the period of the rotation. This was the more often advocated cause for the variability of some Ap stars, and this idea was much developped for example in Moscow, by Khokhlova and her co-authors. However, should we compare that kind of description with solar spots ? Not really ... According Khokhlova, the difference between "metallic" regions and normal parts of the stellar surface is purely one in chemical composition, which makes of it, if true, a phenomenon quite different from the solar spots, -colder than the normal Sun but of about the same chemical composition.

It is difficult, in one respect, to compare the Sun to many very particular spotted stars; I mean to mention those stars of which one side is bright and hot, due to tidal effects, or illumination effects, linked with the existence of a close bright companion. Many stars are members of double systems, and deeply influenced by this situation. The Sun is definitely not, -even if one assumes Jupiter to be a very small stellar-like object.

Do we have some hope to detect spottedness, at a scale larger than on the Sun, but of the same nature ? Drift-velocity curves, of some low excitation and low ionisation lines could indeed be looked at, to determine the rotation period. Periodical variation in the continuous flux should be associated with them. To my knowledge, not much has been done in this respect. It is obvious that if spots are similar to solar sunspots, they are not detectable as yet although the time may be very close to enable us to detect solar-like spots ... Even during maximum, the total solar flux is diminished by a small factor (of the order of 10^{-4} to 10^{-3}), not yet detectable on a star. On the other hand, very large spots would basically affect the whole stellar structure and modify magnetic fields, rotational behaviour and the like. The spot behaviour and the spot physical properties might then have nothing to do with that of the solar spots ...

The best hope to study stellar spottedness is the speckle interferometry which already allows us to observe directly the limb-darkening of some very large stars, such as Betelgeuse or Mira Ceti. Multimirrors systems, such as the MMT 10 meters-complex, or the arrays of distant mirrors now under construction by Labeyrie at the Cerga may be a promising technique. Wait and see ! The resolving power is now of the order of 1/100 th of an arc second; it can certainly be largely improved, only by the existing projects, such as the ones in the Cerga, in ESO, or in Arizona.

5. The solar flares and the flare stars

One of the most beautiful and conspicuous phenomenon that can be seen in an active solar region is of course the flare. Observable in X rays and in the radio-wavelengths, as a rapid function of time, and with rapidly changing spatial configuration in a complicated magnetic area of the solar surface active, they display a variety of properties of which we shall certainly talk much in the coming days. Their main characteristic is the output of energy in the form of radiation (emission lines, and enhanced continua), taken almost certainly from the reservoir of magnetic energy distributed all over the Sun and which can dissipate in a few decades, being rebuilt out from the rotational convective energy of the Sun.

On the other side, we know many types of flare stars. Not to speak about the very special cases of novae, or supernovae, we can mention the cold M stars, of type UV Ceti, and the T Tauri stars as typical of flaring stars. We should a priori eliminate those stars of which the flaring is due to the dissipation of some obscuring matter such as are probably the stars of the type FU Orionis, for example, which drastically change their spectral type, from before to after the flaring.

But can the T Tauri and the UV Ceti benefit of our studies of flares, or can they conversely help us to better understand solar flares ?

Some cases may be quoted, of recent studies. In the case of YZ C Mi, Whitehouse has been proving the simultaneity of flaring in X-rays, radiowaves, and visible emission lines. In the case of BY Draconis, the flares seem superimposed on top of a cyclic variation of an amplitude of some tenths of magnitude, the flaring occuring near maximum periods of maximum light, suggesting a phenomenon similar to the solar cycle, but with a small cyclic period, and a large spottedness.

What can we say about SS433 ? To keep the eyes open is the only rule for the (solar) physicists. Some mechanism could be there at work that could be moderate on the solar surface; one is temptated to associate SS433 phenomena with bursts of type III, which moves through the solar corona with velocity of one third the velocity of light ...

The continuous survey of X-ray sources, together with optical studies of their visible counterpart is a very promising way of study of these flares, as shown at the Uchinoura launching station optical telescope by Matsuoka and his co-authors. An interesting case is that of the radio-source Sgr A, -the center of the Galaxy, which after all may be stellar-like, and which is certainly flaring in the X-ray.

As many phenomena are linked with optical solar flares, many must be associated also with the flaring of the flare stars. One has looked, unsuccessfully I believe, in the radio wavelengths, for possible flares of T Tauri, UV Ceti and other similar stars. I shall certainly be interested, during the course of this conference, to hear form our radio-colleagues what they do expect to observe in this respect in the coming years.

6. The solar and stellar magnetism

More difficult is still be study of stellar magnetism and its variation. There are methods which allow to determine the magnetic r.m.s. field, from magnetic intensification, i.e. from curve of growth analysis putting in evidence the differential behaviour of lines with high and low Landé factor. In the Sun (M. Fitremann, private communication) a stochastic r.m.s. field of 100 to 200 gauss seems to be present;

more studies are underway; in the stars, similar effects could be easily detected.

But the strong fields that are observed in the center of the umbra of a sunspot are seemingly out of reach, for the time being; a much better angular resolving power could only enable to get to it. The speckle techniques might do it, or the multimirrors, and arrays equipments. But this is not for tomorrow, -perhaps the day after tomorrow !

In stellar cases, the use of polarization is hardly a way to determine magnetic fields; the only possible way is to use the Zeeman splitting, in the spectrum of the whole stellar disk. Since 1948 one knows the general magnetic field of 78 Vir of the order of 500 Gauss. Many peculiar A stars have fields ranging from 100 to 30000 G, or so. Rayrole has shown for 53 Cam, that a 3800 G field exists. Unno, and Kato have been making use of other determinations. In many cases the field is variable. Often variations in the spectrum, or in the brightness, do confirm somewhat the comparison between spotted regions and non-spotted regions of the solar surface. It seems that the field strength and the luminosity are correlated sometimes (53 Cam) but often also anticorrelated ! On the Sun, it seems that there is some kind of compensation. Spots are cold, but faculae are hot with respect to the so-called quiet sun; as a whole, it is not obvious that the spotted solar surface at maximum activity surface is on the average darker than the solar surface at minimum solar activity.

Variations of the solar constant throughout the solar cycle have been seeked for, and only guessed; variation in the IR, anticorrelated apparently with the total brightness, indicate a change in the average structure, -but the spotted surface is so small than the solar effects can be considered as linked more to the facular behaviour. In the case of heavily spotted stars, it could very well be the reverse; and more studies, especially in the IR, could lead to interresting results.

Theories of stellar magnetism link it, as in the solar case, with the dynamo effect of the rotation combined with the existence of convective cells. To say nothing about the case of binary magnetic models, one should perhaps pay some attention to the oblique rotators theory, which incidently, allows to eliminate the consequences of Cowling well-known theorem (according which a completely closed and symmetrical poloïdal field would not be stable). The period of magnetism in oblique rotators is that of the rotation itself, and has nothing to do with the cycle. We should remember here that Trellis has shown from 150 years of heliographic data, in a way which has convinced only very few persons (but I am amongst the few) that the Sun was a very weak oblique rotator, the inclination of the axis being of the order of 0.5 degrees; the magnetic axis precesses around the rotation solar axis with a period of about 7 cycles.

It may be interesting to note that magnetic fields exist in some cepheids; the effect of magnetic field on the structure and pulsational properties of cepheids may be sufficient to explain the discrepancy between masses of cepheids, when estimated either by the pulsational or by the evolutionary theories. Magnetic pressure has to come in the equations and to possibly make the trick.

7. The solar and stellar cycles of activity

One may identify active feature time changing phenomena, magnetisms or winds, on any given star. But another problem is the existence (or not) of a cycle of activity, undoubtedly to be linked with the internal structure of the star, taking into account the necessary coupling between : rotation; differential rotation (of course); convective motions at large scale, able to transport kinetic momentum; and the overall structure of the magnetic fields. It is even difficult to ask the question in a clear way ! When one sees a time-variation at any given scale, of any given feature, -can one say that it is an isolated phenomena, individual so to say (some large flare, localized, or some important explosive event) ? Or is it only the statistical result of events occuring individually, at much shorter time-scales, and statistically resulting in a quasi-periodic variation of the overall activity ? I do notwant to say much more at this stage !

Possible ways of detecting a cyclic activity could be seeked for in stellar studies, essentially through some of the studies we have mentionned earlier. Measurements of the overall magnetic field, behaviour of oscillations along the cycle (a study to be done also in the case of the Sun), behaviour of P Cygni profiles with time, evolutions of stellar winds, of chromospheric and coronal indicators, of flare occurrence... It means indeed a very large program of studies, but a very fascinating one, of which very little has been done so far, except precisely in the case of solar-like cycles by Wilson and associates.

Could we think over the detection of more than the 22 years cycle ? Grand cycles, like the Gleissberg 80 years or the Yoshimura 55 years, could they be detected ? Or even the Link 400 years-cycle ? They could be studied only for stars of which the normal magnetic activity cycle could be much shorter than that of the Sun. The case of BY Draconis might give a candidate for further studies ... But I feel we should be very patient and careful in that sort of blind studies, which are possibly not blind alleys !

Concluding remarks

It appears clearly that, in most of the fine structure active solar phenomena, especially those of which we shall speak in the coming days, it is not much, in a reasonable amount of time, that we can hope to observe in the stars. The vague behaviour of magnetic stars exists in the stellar world. But not much in term on physical understanding can be expected from their studies, except possibly the behaviour of a few phenomena with T_{eff} or with gravity ... So the Sun is still the only way to reach that kind of phenomena which certainly do affect deeply the stellar structure, without being yet observable in them in good enough conditions. We have two ways of approach in front of us. For faculae, active regions, flares in them, -the Sun may give hints towards the physics; the important parameters may emerge, and orient us to the study of those stars the more likely to display them. On the other side, the systematic study of what we can observe in stars, similar to solar phenomena, may orient the study towards a systematic statistical determination of the influence of T_{eff}, of g, etc ..., hence reorienting again the theory in one direction or another.

The Sun is an active star. All stars are active. Hence the study of solar activity is a prototype study for study of stars; just as the quiet Sun has been a prototype for the stationary description of stars, -now well advanced, but valid of course as an average solution description of any star, not more. On the other side, the study of active -like phenomena in stars may orient the theory of the mechanisms of solar activity. Clearly the theoreticians have to keep two eyes open, -and in two different directions ! It may be somewhat uncomfortable, but it may be very fruitful ...

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