PROSPECTS FOR STUDIES OF UV CET-TYPE FLARE STARS

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ABSTRACT. The present review addresses selected questions on UV Cet-type red-dwarf stars primarily concerning the physics involved in the various aspects and phases of the flare phenomenon, rather than the average activity behaviour of the flare stars. In fact, while flare activity level and general trend are reasonably well established, a fully consistent physical picture of both solar and stellar flare events is still missing. Some recent results are presented with the aim of showing which observations are needed and the relevant role that coordinated multiband studies can play.

1. INTRODUCTION

The UV Cet-type stars in the solar neighbourhood play a fundamental role in the study of flare stars located in different clusters and associations, a role comparable to that of studying solar flares for the purpose of understanding the physics of the flare phenomenon in stars. The latter is a heuristic approach because it is still to be demonstrated that flares on UV Cet-type stars are solar analogues and their flaring behaviour could be considered only a variant of the flaring behaviour of cluster stars, as modified by age or other parameters' effects. On the other hand, it is quite obvious that "interdisciplinary solar - UV Cet - cluster star" flare studies could be mutually profitable, even if, eventually, we shall only be able to prove that we are dealing with completely different phenomena.

The flare activity of UV Cet-type stars has been the subject matter of several internationally coordinated

L. V. Mirzoyan et al. (eds.), Flare Stars in Star Clusters, Associations and the Solar Vicinity, 371–391.

studies and dedicated observations in the past twenty years. Their activity behaviour, as a group, may be considered well established thanks to the statistical investigations by the Crimean astronomers (Gershberg and Shakhovskaya 1983, Shakhovskaya 1989, and references therein), who have carried out fundamental works in this field by analysing more than 2000 optical flares in a few dozen of stars observed during the course of several thousand hours of photoelectric monitoring obtained at several observatories.

The following general results appear to be well established.

a) UV Cet-type flare stars in the solar vicinity form a rather mixed age group, which includes young and old disk, and, possibly, even halo objects.

b) The distribution of the total energy emitted in the B-band during flares E(B), versus mean occurrence rate of flares with energies exceeding E(B), shows a linear correlation in a log-log scale, i.e., the so called "flare energy spectra" can be represented by a power-law with spectral index $\beta \approx 1.0 \pm 0.5$ given by the slope of the linear dependence in the log-log representation. The β index shows a moderate tendency to increase toward fainter stars. A similar trend, spanning over several decades, is shown by Orion and Pleiades flare stars and the Sun, at the high and low energy ends of the distribution, respectively. Therefore, stars of quite different ages, masses and physical conditions, behave very similarly. This strongly suggests that the flare triggering agent, and especially the involved mechanisms, though obviously dependent on the physical characteristics of the flaring stars, cannot be substantially different, otherwise quite different β indices should result.

c) The maximum values of the time averaged luminosity due to flares (L_f) versus M_V show a systematic decrease toward fainter flare stars, while the maximum values of the normalized ratio L_f/L_{bol} show an upper limit of about 10^{-3}, which is independent of M_V. However, both L_f and L_f/L_{bol} values show a large spread up to three orders of magnitude indicating that stars of almost equal mass and luminosity display quite different activity levels.

d) There is clear evidence that the activity phenomena occurring on a given star at different atmospheric levels are closely connected. Chromospheric Balmer and transition region lines, such as N V, C IV, and Si IV, enhance simultaneously during stellar flares (Agrawal et al. 1986).

A well defined proportionality exists between integrated $H\gamma$ and coronal soft X-ray flux for stellar and solar flares (Butler et al. 1988; Haisch 1989) implying a close link between flare emission from relatively cooler and denser chromospheric regions ($T \approx 10^4$ K) and emission from hot ($T \approx 10^7$ K) and thin coronal plasma. Moreover, Butler et al. (1986) found a close time correlation between coronal X-ray and chromospheric $H\gamma$ line flux enhancements during UV Cet flares observed simultaneously with the EXOSAT satellite and the ESO 3.6 m telescope, respectively. This correlation suggests a close connection between flares and coronal heating. In this context it is important to point out that the mean flare luminosity (L_f) directly correlates with activity indicators at quiescent level, such as the luminosity of Balmer lines (Shakovskaya 1989) and soft X-rays (Doyle and Butler 1985). This means that the atmospheres of flare stars, also in their "quiescent" state, possess the embryonic physical signatures of activity.

Despite the observed stellar flares are often 1-3 orders of magnitude more energetic than solar flares, their characteristic behaviour and time evolution are basically similar. Solar flare data generally follow the empirical correlations between flare parameters found for stars, with the Sun occupying the low energy part of the correlation. For this reason, stellar flares are believed to be scaled up versions of solar flares (see Mullan 1989), though several questions concerning the physical interpretation of the flare phenomenon still remain to be answered.

In order to address basic questions on the so-called solar-stellar connection, the most recent studies of UV Cet-type stars, more than being concerned with the collective properties of flare stars, as a group, have tuned in to the physics involved in the various aspects and phases of the flare phenomenon (see Haisch and Rodonò 1989a, 1989b). This trend has naturally followed the increasingly converging paths of solar and stellar studies especially because of the improvements of time and spectral resolutions of stellar observations and the ever increasing use of new spectral windows, from X-ray, to near-infrared and microwave bands, which have finally become available to stellar flare studies. On the other hand, solar studies have made important progress in the understanding of the flare physics, due to the feasibility of high spatial, spectral and time resolved observations, which are not achievable in the stellar case. For the above mentioned reasons, the Sun has necessarily taken the role of the "rosetta stone" of stellar activity and particularly of flare studies (Parker 1989).

Several thorough reviews on flare stars, flare observations and theory have been given at recent meetings

(Byrne and Rodonò 1983, Gondalhekar 1986, Mirzoyan 1986, Haisch and Rodonò 1989a, 1989b). Therefore, the present paper will not duplicate nor attempt to summarize existing reviews on UV Cet-type flare stars, but will concentrate on selected specific aspects raised by recent observations of stellar flares on cool red-dwarfs and subgiants.

More specifically, the following topics, which are relevant in the interpretation of stellar flares, will be discussed:

a) the inhonogeneous structure of the magnetically controlled atmospheric plasma, where stellar flares occur;

b) the role of wide-band high-speed optical and IR photometry in evaluating the flare energy budget and testing the proposed flare mechanisms;

c) the importance of time resolved flare spectra in investigating the physical conditions of the flaring plasmas;

d) the essential requirement of conducting simultaneous multiwavelength observations to study these short, fast-evolving and non-repeating unique events and the research perspectives.

2. THE INHOMOGENEOUS STRUCTURE OF ACTIVE STAR ATMOSPHERES AND THE FLARE PHENOMENON

One of the most recent and significant progress in the study of stellar atmospheres has been the conclusive evidence that plane-parallel and homogeneous models are only first order approximations especially in the case of active stars. In fact, overwhelming evidence has been collected on the ubiquitus nature of magnetic fields, which play a fundamental role not only in the energy storage, energy release and activity mechanisms, but also in structuring the atmospheric plasma according to its complex and inhomogeneous structure, from photospheric up to coronal levels. As well known for the Sun, the emergence of magnetic flux tubes into the photosphere presides over the formation of sunspots, which are the footpoint of huge magnetic loops anchored into the photosphere and extending up to coronal levels. Flares generally originate in complex magnetic regions, as a result of magnetic loop interactions and energy dissipation, following magnetic field reconnections (see Forbes 1988). This qualitative picture is still far from being understood in detail, despite the huge amount of available solar flare data. However, even a simple, i.e., one-loop flare model can account for most of the observed solar flare phenomenology (see Emslie 1989, Dennis and Schwartz 1989 and references therein), especially as far as the initial and impulsive (= short duration) flare phase, which clearly demonstrates that magnetic loops are the fundamental constituents of flares.

Coronal mass ejection (CME) events generally occur at or before flare beginning, when the amount of energy deposition is so large that cannot be dissipated fast enough by the radiating plasma. CMEs may involve kinetic energies larger that subsequently radiated from the flare site. The formation of a very hot plasma with $T \approx 10^7$–10^8 K, from where CMEs often originate, marks the beginning of a flare at the top of a coronal loop (Figure 1) with the emission of microwave, mainly due to gyrosynchrotron emission, hard X-ray and γ-ray radiation, due to electron-ion bremsstrahlung. The acceleration of electrons and protons along field lines toward the chromosphere leads to plasma evaporation in this relatively denser region (thick target model), as demonstrated by the enhancements of mainly soft X-ray emission, XUV lines, Hα and other Balmer emission lines, and UV continuum. When the accelerated particles reach the most dense chromospheric or even photospheric regions, nuclear γ-ray lines and neutrons can be produced. If the accelerated particles are not sufficient energetic and are stopped well before reaching the chromosphere, soft X-rays are emitted from intermediate coronal levels and the energy transport toward the chromosphere is ensured by the thermal conduction. Due to the highly anisotropic bremsstrahlung cross section, γ-ray and neutron emissions are highly beamed, so that they are observed only from limb flares.

Several questions, however, remain to be answered, especially as far as it concerns the rapid rate of energy release (up to 10^{30} erg s^{-1}) and the acceleration of particles to relativistic energies in a few seconds by what should be a very efficient mechanism. However, the energy conversion, transport and dissipation are ill defined mechanisms, that, in addition to other simplifying assumptions, disregard possibly important effects of the field geometry and topology and of secondary interactions between plasma hydrodynamics and radiative transfer along the loop legs, up to its footpoints. Moreover, the idealized single-loop flare model, which is basically one dimensional, does not take into account the actual configuration of magnetic field lines that is likely to be much more complex, as shown in Figure 2 (from Parker 1989).

Therefore, though important progress has been made in the study of the flare phenomenon, we may say that some fundamental questions still remain to be answered. In a very synthetic way, we may say that we have learned a lot on "what" is a flare, but little progress has been made on "how and why" flares occur. In order to overcome this potentially stalling situation, solar studies are presently aimed at disclosing the finest spatial and energetic

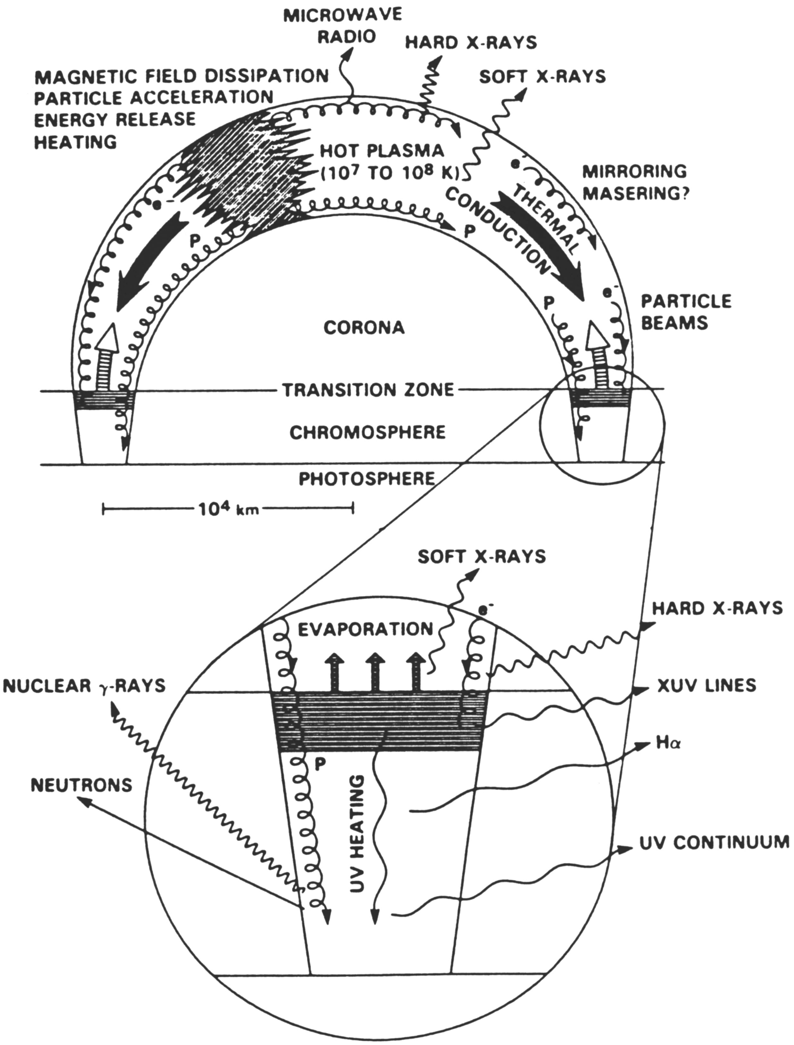

Figure 1. Physical processes and location of the emission sources in the solar atmosphere for a simple one-loop flare model (from Dennis and Schwartz 1989).

details of the flare triggering and emission mechanism, while stellar studies are becoming more concerned with the complementary aspect concerning the development of flares in a large variety of physical ambients, as only other stars, other than the Sun, can offer. For this reason, as anticipated in the Introduction, the present paper will consider only few recent aspects of stellar flare research concerning the flare physics rather than the collective properties of flare stars.

Several shortcomings affect stellar in comparison to solar flare observations, as for example the low level of the available flux, the lack of high spatial and spectral resolution, and our inability to detect γ-rays and neutrons with the presently available instrumentation. However, some specific aspects of stellar flare studies, which are considered in the following paragraphs, are complementary to solar flare studies, in that they allow us to concentrate on the general behaviour of the flare phenomenon versus global stellar parameters and on its cosmic significance.

3. HIGH-SPEED OPTICAL AND IR PHOTOMETRY AND THE FLARE ENERGY BUDGET

Wide-band studies of flares are carried out more efficiently in the stellar than in the solar case because of the much improved contrast between the flare radiation and the quiescent star background. For typical flares on M dwarf stars, the relative flux increase in the U-band ranges from 1 to 100, while for the Sun is much less than unity. This has allowed us to study in detail the energy and time characteristics of stellar flares and their statistical properties, already presented in the Introduction.

Moffett (1972) first pointed out the importance of high time resolution observations of stellar flares. By using time resolutions of 50 ms, he detected short-lived flare structures lasting no more than 2-3 seconds and showing light increase rates as fast as 0.3 magnitudes per second. Subsequent observations with time resolution of 10 ms by Rodonò et al. (1979) with a double-beam photometer, which allowed them to observe simultaneously the variable and a reference star, did give definite evidence on the occurrence of short-lived pre-flare dip and long-term variability of the "quiescent" level. Short-duration spiky flares have been reported by several observers with contraddictory results. (e.g., Zalinian and Tovmassian 1987, and other papers presented at this Symposium). These high-time resolution observations address important questions on the physics of flares, e.g. whether purely

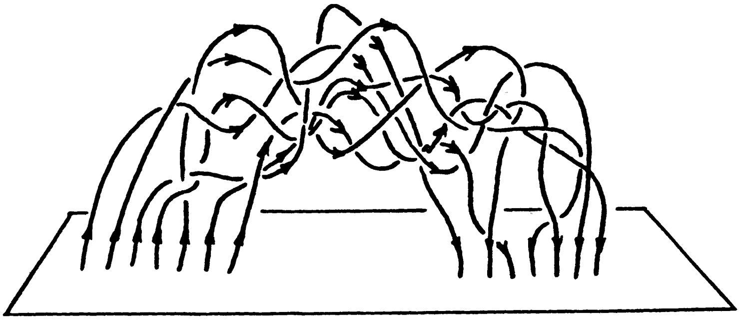

Figure 2. A possible configuration of the lines of force for a bipolar magnetic region (from Parker 1989).

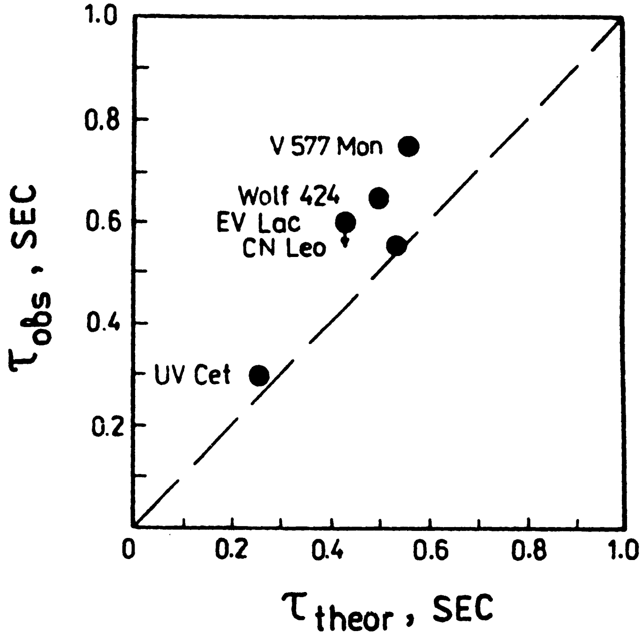

Figure 4. Comparison of observed and theorethical lifetimes of the steepest flare rising phase, the latter from the gas-dynamical model of Katsova et al. (1981).

thermal mechanisms, which successfully predict the overall spectroscopic features of flares, can also account for the observed flaring on time scales of the order of 1 s. The question of short-lived flares has been recently studied by USSR astronomers by using the so called MANIA (Multichannel Analyzer Nanosecond Intensity Amplification) system fed by the 6-m telescope at the Special Astrophysical Observatory (Beskin et al. 1989a). The MANIA system is able to record the time of arrival of individual photons and to achieve time resolutions as short as 3×10^{-7} s. From the observations of about one hundred flares on eight UV Cet-type dwarfs, they found no evidence of fine structures shorter than about 0.3 s. Moreover, considering only the steepest part of the rising flare phases, Beskin et al. (1989b) found that the flare rise times cluster around 2-3 s with minimum and maximum values at 0.3 s and 10 s, respectively. The shortest observed flare had a total duration of 1.75 s (Figure 3a). According to the gas-dynamic model of stellar flares (Katsova et al. 1981, Katsova and Livshits 1986) the flare rising time (τ) is directly related to the time required by a shock wave front to propagate towards the photosphere along a magnetic flux tube, up to a distance of about one scale height. By comparying the theoretical rise times ($\tau_{theor} = V_s / M g$, where V_s is the sound speed in the chromosphere, M the Mach number and g the gravity acceleration) with the observed values (τ_{obs}), Beskin et al. (1989b) conclude that the thermal gas-dynamic model is adequate to interpret the impulsive start of the optical flare behaviour and that the decay time scales are consistent with the recombination times of optically thin plasma or the cooling times of optically thick plasma heated by the energy dissipation of shock wavesduring the initial phase of flares (Beskin et al. 1989c). The revival of high-time resolution photometry of stellar flares by the USSR astronomers is particularly important also because such data cannot be obtained for solar flares due to the high solar background level.

The existence of short-duration quasi-periodic light oscillation during flares is an additional question that high time resolution photometry can address. After Rodonò's (1974) observations of quasi-periodic 12-14 s light oscillation during the course of a flare on the Hyades star Hertzspung II 2411 and Mullan's (1976a, b) interpretation in terms of electron cyclotron waves ("whistlers") travelling from one magnetic pole to the other, no additional optical evidence has been collected. Oscillatory behaviour also at radio-wavelengths has been reported (see Gibson 1983). The onset of oscillations during stellar flares is a virtually unexplored field, although it is of great interest for the purpose of understanding the flare mechanisms and energy dissipation modes. Some interesting

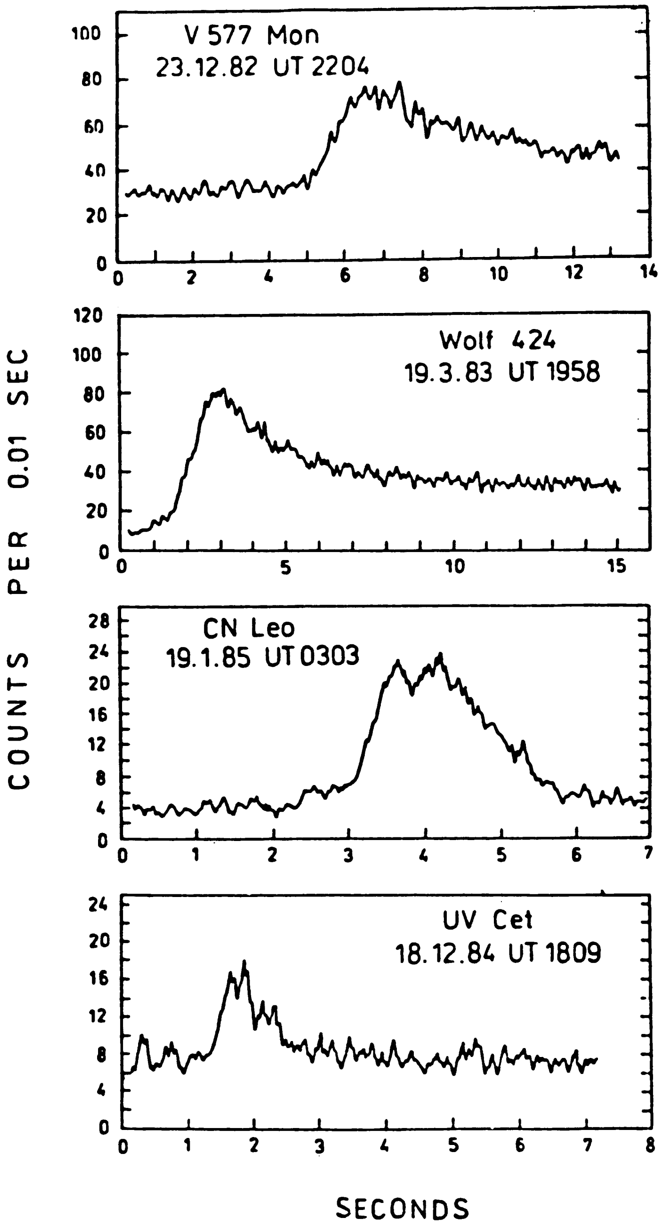

Figure 3. High-speed photometry of stellar flares obtained with the MANIA photometer fed by the 6-m telescope at the Special Astrophysica Observatory, USSR (from Beskin et al. 1989b).

and very promising results have been recently obtained by Andrews (1989, and references therein).

Another important aspect of wide-band flare studies is the energy involved in the various spectral regions. As shown by Gershberg and Shakhovskaya (1983) statistics, the total optical energy output during the course of a stellar flares on UV Cet type stars is in the range from 10^{27} to 10^{34} erg. Taking into account the energy emitted in other wavebands, the flare total energy budget very seldom increases by at most one order of magnitude. From simultaneous optical (U) and infrared (K) photometry, Rodonò and Cutispoto (1988) detected for the first time "negative" infrared events at wavelengths longer than 1 μm in coincidence with optical flares (Figure 5), as predicted by Gurzadian (1980) non-thermal and Grinin (1976) thermal models. At present it is not possible to draw any conclusion about the validity of these flare models because only a few events have been observed. One important question raised by these IR observations concerns the flare energy budget. The missing energy due to the K-band "negative" flare is about one order of magnitude larger than the energy released in the U-band, i.e., the energy missing in the K-band alone can account for the energy released in all other spectral regions. Additional observations are needed to reach a definite conclusion on whether this result is directly linked to the shift of photospheric photons towards shorter wavelengths by their inverse Compton interaction with fast electrons, as first predicted by Gurzadian (1980, and references therein), or can be accounted for by the increase of H^- opacity during the very first phase of flares (Grinin 1976). The amplitudes of the observed "negative" flare are consistent with those predicted by both models, but the infrared flare light curve does not appear to be the mirror image of the optical light curve as far as time evolution is concerned. However, since the observed flares are rather complex, they are not adequate for a stringent test of both Gurzadian's and Grinin's models, as the simultaneous optical and IR observations of intense single-peaked flares would be.

4. TIME-RESOLVED FLARE SPECTRA

The relative importance of the basic emission mechanisms that drive emission line fluxes in the optical region during the course of stellar flares are poorly known, mainly because sufficiently time-resolved spectra of flares are difficult to obtain because of the concurrent negative effects due to the faintness of stars and the rapid development of flares. Large aperture telescopes and adequate

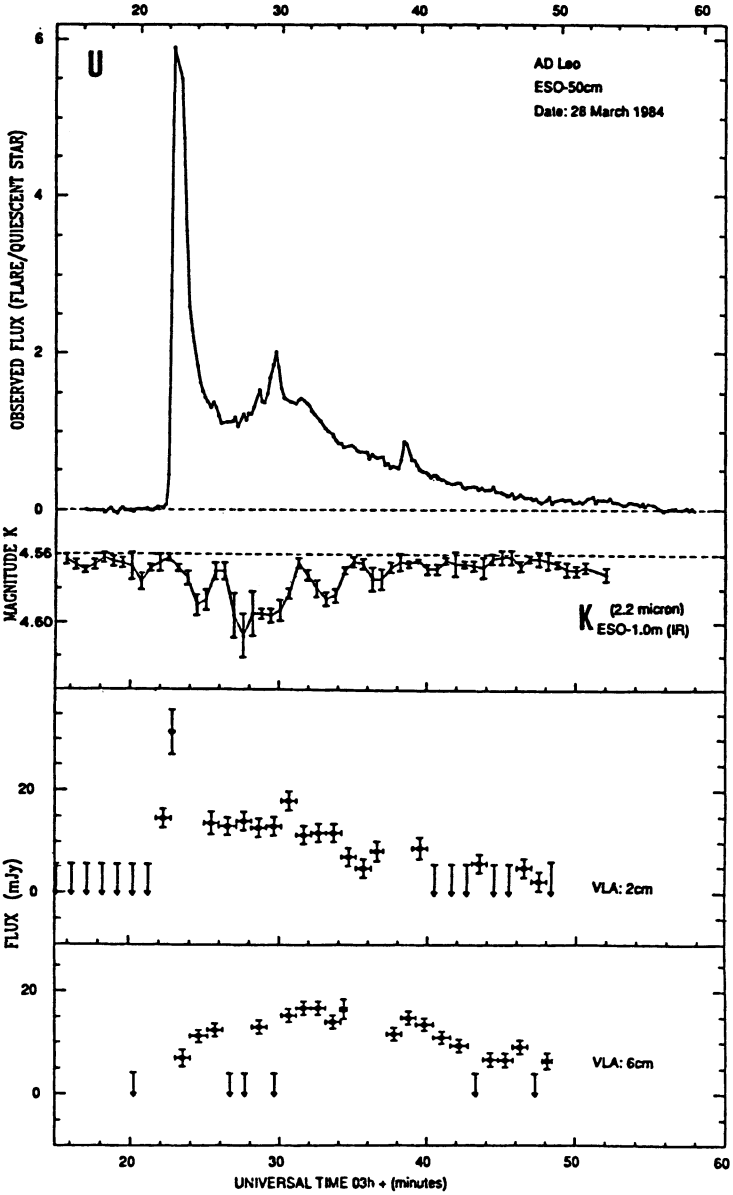

Figure 5. Simultaneous optical (U-band), infrared (K-band), and microwave (2- and 6-cm) observations of a complex flare on AD Leonis (form Rodonò et al. 1989a).

fast detectors are required to achieve that goal.

The best time-resolved and accurate spectra of stellar flares, which are presently available, were obtained by Rodonò et al. (1989a) using the Image Dissector Scanner (IDS) fed by the ESO 3.6-m telescope. These observations show a distinctively different time evolution of Ca II K, He II 4026 Å and Hydrogen Balmer lines, the former line showing a more gradual enhancement and decay than He II and Balmer lines (Figure 6). Houdebine et al. (1989a), have developed line models based on the main atomic processes taking place in a typical flare plasma, assumed to be stationary and optically thin. Their calculations provided convincing evidence that the line fluxes are largely influenced by electron temperature variations. They also showed that during flare decay two main phases can be identified: the first phase is dominated by radiative processes, such as photoionization, and the later phase by collisions. The resulting electron densities for the observed flares range from 3×10^{11} to 10^{12} cm^{-3}, much higher than in previous studies (Gurzadian 1977). Shallow opacities and NLTE departure effects on the higher Balmer lines were also pointed out by Houdebine et al. (1989a). By analysing the same time-resolved spectra of flares obtained at ESO, Houdebine et al. (1989b) showed evidence for a high velocity mass ejection event which occurred at the onset of a particularly violent flare on the M dwarf AD Leo. The plasma was ejected at projected line-of-sight speeds of up to 5800 Km s^{-1} (Figure 7). That event appeared to be similar to solar coronal mass ejection (CME) events, but involving kinetic energy (5×10^{34} erg), mass ejection (7.7×10^{14} kg) and speed values (≈ 6000 km s^{-1}) that are 500, 40 and 5 times larger than typical CME solar events, respectively. The estimated mass loss for various sets of electron temperatures and plasma opacities, combined with typical flare occurence rates, indicates that flare activity may have important consequences on the evolution of active stars and on the composition and physical state of the circumstellar and interstellar medium.

As recently reviewed by Byrne (1989), line broadenings of the order of 10-100 Å in the optical band and line shifts of the order of 10-100 Km s^{-1} UV bands have been reported by several authors. Although only high time and spectral resolution data can provide definite evidence of mass motions within and from flaring regions on stars, similar to the well ascertained mass motions in solar flare regions, the available stellar data, which are usually derived from low and medium resolution spectra, are very promising and encourage to pursue further the collection of high quality flare spectra with time resolutions of few seconds and spectral resolutions of the order of 10^4, by using large aperture telescopes and modern bidimensional

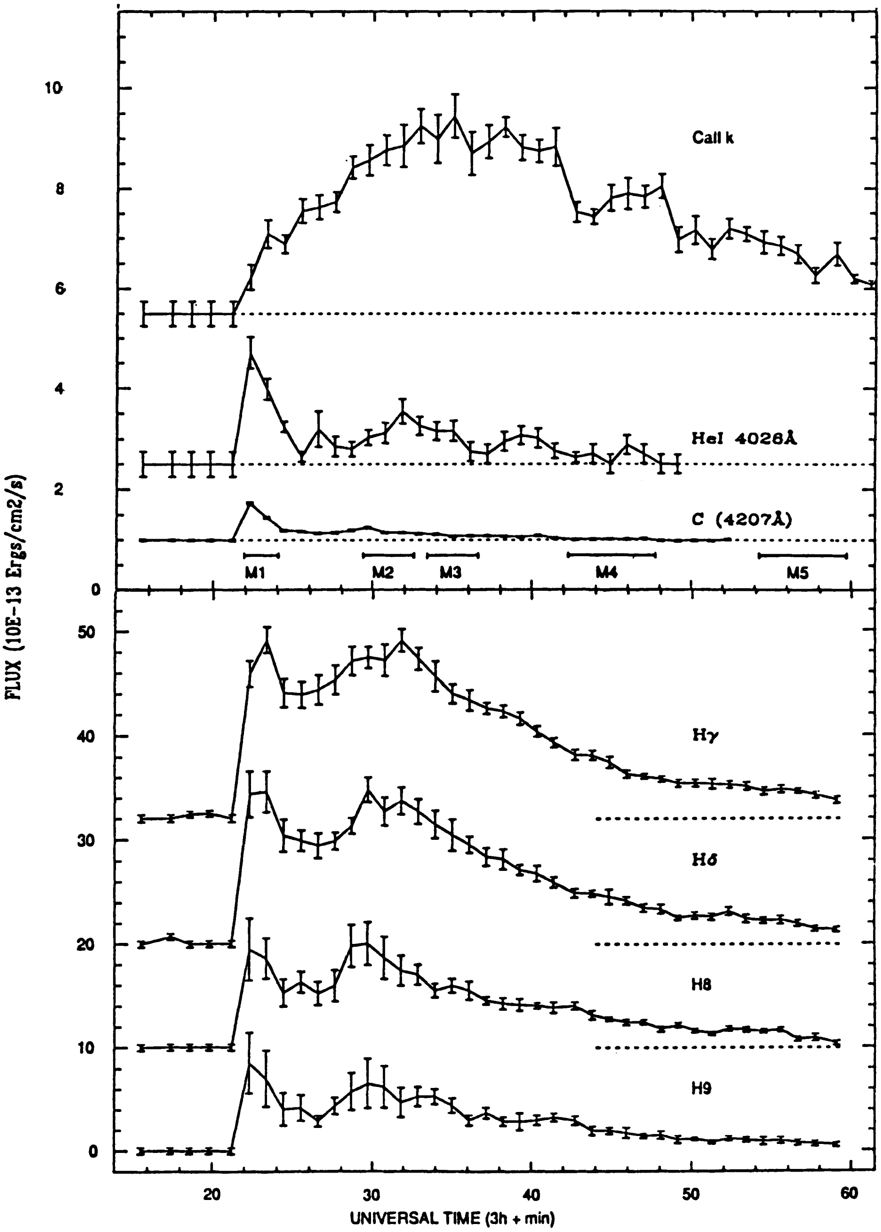

Figure 6. Time development of emission line fluxes during the course of the AD Leo flare, whose light curve is shown in Figure 5 (from Rodonò et al. 1989b).

detectors, such as Charge-Coupled Devices (CCD) or Micro-Channel Plates (MCP).

Some evidence of oscillatory behaviour of Balmer line Doppler shift during the decay phase of a flare on AD Leo was reported for the first time by Houdebine (1989). The question of flux or velocity oscillations, as already quoted in paragraph 3, would deserve to be addressed more systematically with high time resolution photometry and spectroscopy because of its potential importance as a diagnostic tool of the physical conditions of the flaring plasma and flare mechanisms.

In a paragraph devoted to time-resolved flare spectra we should not even mention UV data, the majority of which has been obtained with IUE. As known, this otherwise very productive satellite, does not have the capability of obtaining high resolution UV spectra of flare stars with the required time resolution. In fact, the best time resolved flare spectra have been obtained with the low-dispersion camera and with time-resolutions of the order of minutes. Therefore, only time-averaged flare parameters could be obtained (see Byrne 1989). Instead, long duration flares on bright RS CVn stars have been studied in some details. By using the so called Doppler Imaging Technique, Linsky et al. (1989) were able to extract pure flare spectra and derive line profiles showing clear evidence of mass motion. Nevertheless, IUE has allowed us to make important progress in the study of flares on dMe stars. All choromospheric and transition region lines are strongly enhanced at the time of flares and the degree of enhancement increases with the temperature of line formation, as observed during solar flares. This is primarily due to steepening of the temperature gradient in the upper chromosphere and transition region, which during the course of flares is pushed down towards higher density atmospheric levels. From time integrated flare data, electron densities of the order of 10^{11}-10^{12} cm^{-3} and integrated energies of a few 10^{32} erg in the transition region line, with emission measures in the C IV line of the order of $1-10\times10^{47}$ cm^{-3}, have been derived.

It is evident that the UV part of the spectrum contains very important chromospheric and transition region line diagnostics. Therefore, it is fundamental that a new generation of large aperture UV telescopes, such as the proposed SPECTRUM UV TELESCOPE of 170-cm aperture, becomes available in the nearest future to allow us to obtain high quality data on the UV spectral behaviour of stellar flares with time resolutions of the order of 10 seconds and spectral resolutions of at least a few thousands.

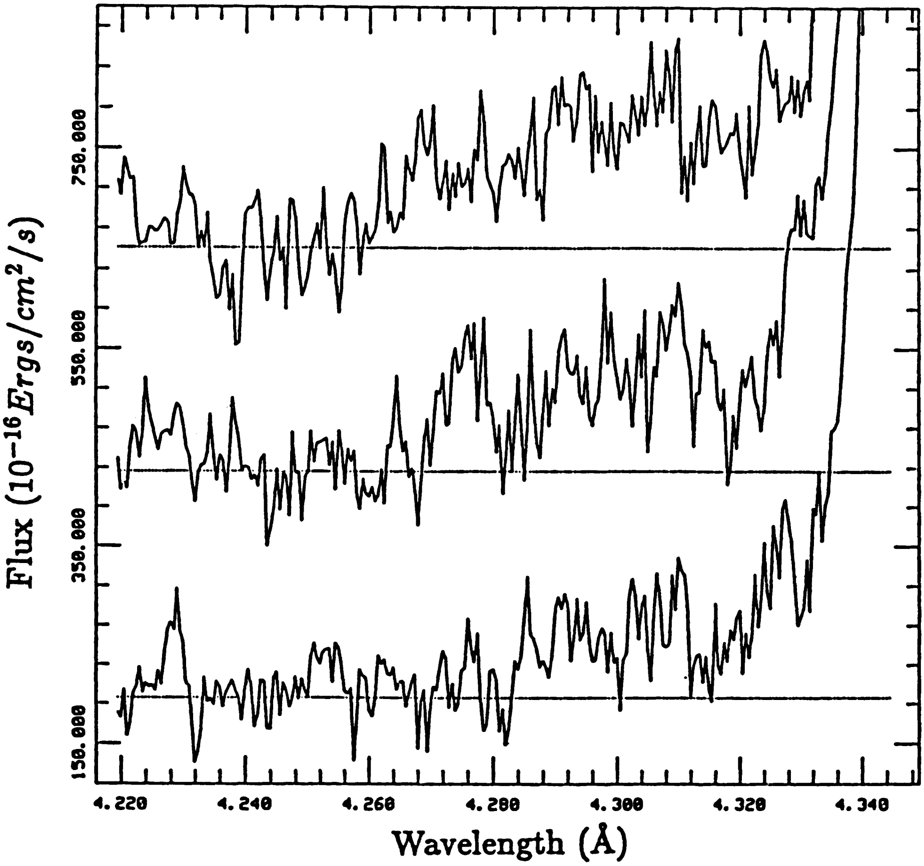

Figure 7. Time evolution of the Hy line profile (from top to bottom) during the first three minutes of the AD Leo flare shown in Figure 5. Note the extended blue wing of the line profile indicating mass ejection with maximum velocity of about 6000 km s^{-1} (from Houdebine et al. 1989b).

5. SIMULTANEOUS MULTI-WAVELENGTH OBSERVATIONS, AND RESEARCH PROSPECTS

Since flares are non-repeating, short-duration and fast-evolving events, which affect almost any level of stellar atmospheres, simultaneous multi-wavelength data are required in order to derive significant information on the physical state of the flaring plasma and on the flare triggering and energy release mechanisms. As emphasized by Byrne (1989), a complete set of multi-wavelength observations including all potentially available spectral regions - from X-rays to microwaves - does not exist even for one single flare, despite so many years of flare studies (see Rodonò 1986). Some efforts have been hampered by instrument failures, wheather conditions, and, unfortunately, sometimes also by unresponsive Allocation Committees of telescope time. Often, in addition to optical data, only one additional waveband has been covered, such as the soft X-ray, UV or microwave band. The most complete data set, which is available to date, include optical photometry and spectroscopy, IR photometry, microwaves, and, in a few instances, also soft X-ray coverage (Rodonò et al. 1989a, Butler et al. 1986). Some relevant results obtained by using these data have been already presented in the previous paragraph. What I should like to stress at this point is that if we want to progress further in the understanding of both solar and stellar flares we must become able to organise further internationally coordinated observations, to be obtained simultaneously in several spectral regions, including many chromospheric, transition region and coronal diagnostics. This implies to observe stellar flares simultaneously with ground-based and space observatories in the optical (U-B-V), IR (J-K-L bands), microwave (2-6-20 cm), low and medium energy X-ray bands, with high time and spectral resolutions adequate to follow the fast time- and spectral-evolution of flare events. In the future, also hard energy spectral regions, such as hard X-rays and γ-rays, should be explored.

One of the neglected aspects of flare studies is their occurrence in binary systems. Actually, the magnetic field configuration in binary systems may extend over the entire system with magnetic loops connecting the two stars, as proposed by Uchida and Sakurai (1983) and Uchida (1986) and suggested by the IUE observations of an intense flare on the RS CVn-type system UX Ari (Simon et al. 1980). Almost simultaneous flaring of both components of binary systems in the optical (Rodonò 1978) and radio wavelength bands (see Gibson 1983) is another neglected topic that would deserve dedicated studies. In order to make some progress in the study of binary flare stars, we should also aim at high spatial resolutions by using interferometric techniques, both at radio and optical wavelengths.

Finally, long-term flare activity cycles, similar to and likely associated with spot cycles as in the Sun, have not been studied in a systematic way, despite their obvious importance.

The main problems with long-term systematic studies of stellar activity resides over the difficulty of obtaining sufficient telescope time and the heavy work required by dedicated and systematic observations, which sometimes are not sufficiently rewarding. Automatic Photometric Telescopes (APT), being able to perform robotic observations (Genet et al. 1987), will give new impetus to stellar activity studies. An international APT network and coordinated collaborative programs, such as SYNOP promoted by J.L.Linsky (see Giampapa 1986), MUSICOS promoted by B.H.Foing (1989), and ODIN promoted by B.R.Pettersen (1989), will certainly give sufficient momentum for a decisive step forward in our understanding of a relevant astrophysical phenomenon, whose cosmic significance has not yet received due recognition.

Acknowledgements. Solar and stellar activity research at Catania University and Observatory is supported by the "Ministero dell'Università e della Ricerca Scientifica", the National Research Council ("C.N.R.: Gruppo Nazionale di Astronomia") and the Italian Space Agency (A.S.I.), that are gratefully acknowledged.

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MIRZOYAN: You don't say anything about the evolutionary status of flare stars. Maybe the title of your paper do not permit you to do this. But I must express my disagreement with your opinion that the Sun is the only source to interpret stellar flares. I think that no less important for this problem is the study of flares in the star clusters and associations and of fuor-like changes. I hope that this study can contribute to the interpretation of stellar flares and may be even flares on the Sun.

RODONO: My talk was concerned with the physics of flare phenomena and the difficulties of interpreting them, and the evolutionary aspect was reviewed by you at the beginning of this Symposium. When I said with Parker's words that the Sun is the Rosetta Stone of flare studies, I did not intend to say that it is the only source of inspiration to study stellar physics. Actually, the study of flaring events on different stars will have a key role in this respect.

PALLAVICINI: Are there any observations of solar flares in the infrared showing a similar phenomenon as that reported by you for stellar flares?

RODONO: None as far as I know. White light flares on the Sun have been observed only recently in a systematic way and up to about 6000 A.

PALLAVICINI: Could the blue-shifted components you found in UV lines be due to evaporation of chromospheric material as sometimes observed for the Sun?

RODONO: The amount of mass implied by the observed blue-shift seems to be too large to be accounted for by chromospheric evaporation?

LANG: The solar analogy cannot be pushed too far when it comes to the radio emission of flare stars. When radio flares are seen at the same time as optical or X-ray flares in stars,the radio emission is very weak and sometimes absent. At other times there are strong radio flares with undetectable emission in other spectral domains. In contrast, the Sun radiates strong flares at the same time at optical,radio and X-ray wavelengths. Also, the quiescent emission from YZ CMi is a few mJy at 6 cm, and it is nearly always present, so it is stretching the imagination to associate emission at this level with optical and X-ray flares.