# FLARES AND FLASHES:

# PAST AND FUTURE

# ROUNDTABLE DISCUSSION

https://doi.org/10.1017/S0252921100035533 Published online by Cambridge University Press

# Flares And Flashes: The Future

*Round Table Discussion*
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**Vanderspek: Introduction**
The goal of this round-table discussion is to bring up issues which may be of mutual interest to those working on specific flare and variable stars and those performing wide-field searches for, among other things, counterparts to gamma-ray bursts (GRBs). Admittedly, however, trying to unify the interests of the flare people and the GRB people will be an interesting task. Many of the presentations this week have been devoted to future instrumentation and future modes of observations, but there have been also interesting discussions of specific questions regarding flare stars, variable stars and GRBs. Certainly, wide-field observations of the night sky will continue for the foreseeable future: there are a lot of instruments running now, and there are many instruments being planned. Most of these observations cover many square degrees of sky for long periods with a reasonable magnitude limit. How could these observations could be modified or improved to also allow useful data on on variable stars or flare stars to be taken? What sort of information, statistics, periodicities could be gleaned from wide-field searches that will be happening in the future and searches that are going on today? Are there methods in common use by one group of observers that may be useful to the other?

The speakers in this session have volunteered to give a short presentation on issues which may benefit from discussion within this group.

**Merck: Ground-based TeV observations of GRBs**
I want to tell you about the efforts that have been made in TeV astronomy to follow up GRBs. Before I came to *EGRET*, I was working on the *HEGRA* experiment, the High-Energy Gamma-Ray Astronomy observatory on the island of La Palma. It is one of the big arrays, and it is now complemented with a system of Čerenkov telescopes and all the inventory of techniques of ground-based gamma-ray astronomy. All groups working in ground based gamma ray astronomy got very excited with the results of *BATSE*, especially because of the delayed high energy emission seen by *EGRET*. The high rate of cosmic ray events normally is a big background for ground-based gamma ray astronomy. On the other hand, bursts have very short duration and one may easily detect them with ground-based instruments, as they are essentially background-free on these small timescales.

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To search for bursts *HEGRA* has been connected to the *BACODINE* system. Of the system of five imaging Čerenkov telescopes, two are operational. The remaining three will come on-line in 1995. The telescopes are similar to the Whipple telescope but with less mirror area, so that we have a higher energy threshold (around 1 TeV). The burst observation mode is the following: after a *BATSE* trigger, we determine if the position is visible from our location. If this is true we will point the telescopes to the given best position. All Čerenkov observations are only possible during nights without moonlight so only bursts during these time intervals can be followed up. The telescopes will be pointed to the region of the sky where the burst happened for a second night after the burst to cover all possible delayed emission. After this, the telescopes will return to their target assigned by the normal observational program. The scintillator array has been operational for five years: very interesting limits on GRBs were presented at the Huntsville meeting.

The third instrument in operation at La Palma is a very interesting Čerenkov array. Its performance is much better than that of the scintillator array: it has a much better angular resolution (5′) and a lower energy threshold (25 TeV). I think we can lower this threshold to 10 TeV with the present design by improving the electronics and we think that with an improved second generation experiment an energy threshold of 1 TeV is feasible. This Čerenkov array consists of nearly normal photomultipliers with a Winston cone assembly to collect the Čerenkov photons. Each photomultiplier views one steradian of the sky the whole time. A normal photomultiplier would be destroyed by this high background light level in about 10 minutes, thus specially designed multiplier with a reduced amplification, having only 6 dynode stages, is used. The rest of the amplification is done electronically. The noise is further reduced by a linear gate which picks out a very short time around the photomultiplier signal, thus reducing the contribution of the night sky background. Using a coincidence trigger of 12 such detector stations, we can reconstruct the Čerenkov light front of the air shower. This front is very well defined, with a thickness of a few nanoseconds. With special filters it could become possible to use this technique also during nights with moonlight.

To push the energy threshold down to 1 TeV we are testing the Quasar type photomultipliers from Russia, the ones used in the Lake Baikal experiment, which are much bigger (25 inch diameter). The number of Čerenkov photons from a 1 TeV air shower collected with such a multiplier should be sufficient to dicriminate against the night sky background noise. We are considering an experiment consisting of a 1 km$^2$ array of this type. Technically the event rate of a few hundred million events per night is challenging, but solvable. We don't have to move them to a *BACODINE* location, because they will have one steradian, *i.e.* a section of the sky with $\approx 40°$ opening angle, in the field-of-view of this detector the whole time.

I think that if there is emission in the TeV range at the level you may expect by extrapolating the GRB spectra, we should be sensitive with this type of instrument to all of the *BATSE* bursts. Those events with the highest fluence, those which were also detected by *EGRET*, should be detectable with our present system if the spectra can be extrapolated to 10 TeV.

Moving the telescopes is a problem, as we were thinking about using our Čerenkov telescopes as an optical monitor for bursts. If an optical flash happens, and it is very short in duration, say 1 millisecond (the typical timescale for the collapse of the core of a merging neutron star into a black hole), the photomultipliers are the best way to detect this. You will be much more sensitive than with photographic plates, which integrate over a long time. But the problem is that you can't move your telescope very fast and the probability is very low for getting a burst in a $3^\circ \times 3^\circ$ field-of-view by chance: my calculation gave 1 coincidence for 15 years of *BATSE* triggers.

With the wide field-of-view Čerenkov array we did search for emission from AE Aquarii, and we didn't find anything. We had an observing campaign this summer with the Čerenkov telescopes, which was supposed to be in collaboration with the Potchefstroom group. They didn't get their telescopes working so no correlations are possible. A very preliminary analysis of our data showed no obvious signal. I think we should have seen a signal of the size the Potchefstroom people claimed as a $100\sigma$ excess. It should be quite obvious in a first analysis and no such signal was found.

**Hudec: Future strategies for optical searches for GRBs.**

Monitoring individual $\gamma$-ray burst error boxes for transient optical radiation is difficult in that there are so many of them and the repetition rates are low. An alternative approach is to monitor many gamma ray positions simultaneously. We have developed the idea of the *OTM* (optical transient monitor) experiment to get a very large field-of-view of $\approx 50^\circ$ diameter, in which case $\approx 30$ or more gamma ray positions can be monitored simultaneously. The *OTM* is based on wide field optics and a CCD camera, which we expect to have something like $1000^2$ pixel, and a sensitivity for stars of between $10^m$ and $12^m$.

Simultaneous optical observations of GRBs to date almost all have a limiting magnitude for a one-second flash of between $0^m$ and $3^m$. With the *OTM*, we expect to have a one-second limiting magnitude of between $5^m$ and $6^m$. Our idea is to look for a final confirmation that optical transients are indeed real. We would like to operate two such stations, separated by about 100 km to get very good parallax, to be able to eliminate all triggers which could be coming from the Earth's atmosphere (such as satellite flashes). The real flash must be located on the frames from both stations, and must be at the same time and the same position: then we can be finally sure it is the optical counterpart.

In addition to this system, which is optimized in the red part of the spectrum (as are most wide-field surveys using CCDs and lenses), we are trying to develop a wide-field optical system which is more sensitive in the blue. Because our analysis of the Schaefer 1928 OT shows that the image is real, not a plate defect, we conclude that the differences it shows from neighboring stars is due to the fact that the flash is very blue. The system we are developing will use a CCD with blue-enhancing coating and wide-field optics that are optimized for better blue transmission.

**Vanderspek: The Explosive Transient Camera**

I would like to briefly review the Explosive Transient Camera (*ETC*) and its possible use to look for flare stars and long-term variables. Each night, the *ETC* stores several sets of full $20° \times 15°$ images of the night sky from all sixteen cameras for later analysis. Among the images stored in this manner during the course of a year, one can find each part of the sky between $-15°$ and $+60°$ imaged roughly sixty times. To date, we have collected over 36 000 images over the last four years. We are in the process of analysing these images. We process each image by looking for stars in the field, and perform astrometry and photometry on each star detected in the field. We have right ascension, declination, magnitude and its error for 1000-2000 objects on each of these fields down to a limiting magnitude between $9^m$ and $12^m$, depending on the night and the optical system used. When the analysis of these images is complete, we will have 30 000 000 brightness measurements of roughly 100 000 objects, and we are sure to see transient phenomena among the data.

In the beginning of 1995, we will install some new CCDs which will increase the field-of-view by a factor three. We will have about the same limiting magnitude, and the pixel size is slightly more than $3'$, but we will be able to collect data from significantly more objects over a significantly larger declination range.

I would like to mention that when the High Energy Transient Experiment (*HETE*) launches and all work wells, we will be taking full images of the night sky in a near UV band between 230 and 270 nm with a FoV of $40° \times 40°$ roughly $10 - 40$ times per night. We plan to collect a large database of UV images, and the potential for detecting variability from flare stars and other sources is enormous.

**Vanderspek: GRB error circles and wide-field observations**

The situation for looking for optical counterparts for GRBs so far is not very encouraging: many workers have spent many years looking for them, and none have been seen. However, when Rene Hudec and Jochen Greiner described their work, one result really stood out: they have 55 full sky plates of GRB error regions taken during outburst and they have not seen any transient optical radiation. This tells me that we aren't going to see anything if we continue to look with such wide fields. The future is smaller fields, where you can go to deeper limiting magnitude. One difficulty in going to smaller fields-of-view is that the error circles derived by *BATSE* alone are rather large ($4°$-$8°$ $1\sigma$ radius). The *ETC* has imaged the region of the sky where *BATSE* detected a GRB at the time of the GRB on five separate occasions, but we have not been able to make a firm statement about the presence of transient optical radiation because of the size of the error circles. Gerry Fishman has told me that there is some promise in reducing the size of the *BATSE* error circles.

**Fishman: BATSE error circles**

Before saying something about the error circles, I would like to tell you about the prospects for *BATSE*, because there is so much activity with coordinated ground-based observations. You might wonder if this all will be for nought. Will *BATSE* continue to operate? I don't have a crystal ball. I don't know what

https://doi.org/10.1017/S0252921100035533 Published online by Cambridge University Press

the future political or economical situation will be. The ongoing astrophysical missions will continue to be reviewed every 2 or 3 years. As my personal feeling the prospects are very good that *BATSE* and the *CGRO* will operate for at least another 5 years. There is a fair chance that it may operate 10 years.

As far as the error boxes from *BATSE* are concerned, I don't need to apologize. The best we can do right now is of the order of $3-4°$. There is some prospect for improving that of the order of 2°. The basic limitation is that *BATSE* is uncollimated: there is no focussing or lensing, there are just flat plates. There are systematic errors that are being improved: the largest of those are atmospheric scattering, non-linear energy calibration, and spacecraft scattering. As we are getting more bursts and as we are getting more calibrational location from the interplanetary network and solar flares, we will be able to reduce this. I doubt that we ever get better than 2°.

Concerning burst location determination in real time, we can't do that well because we don't have access to all of the data that is required to make all this corrections. The best we will be ever do with the real time *BACODINE* locations probably will be of the order of $6-8°$. Maybe there is a chance of improving that to maybe $4-5°$ at $1\sigma$ radius.

**Seitter: The Muenster Redshift Project (MSRP)**

I came here to listen and to learn, but some of the contributions made me aware of the fact that at Muenster we are actually doing things which might be of interest to this audience, especially in view of some pilot projects which we have already carried out.

The Muenster Redshift Project (MRSP), aimed at answering questions of observational cosmology, as a by-product assembled catalogs of stars from the ESO/SERC Sky Atlas R-plates with red magnitudes $r_F \leq 20^m$ for more than 20 million stars, and from the J-plates with blue magnitudes $b_J \leq 21\overset{m}{.}5$ for about half a million. The blue survey continues.

The corresponding color indices permit us to detect the very red dwarf and giant populations. The means of separating the dwarfs are proper motion measurements, which, so far, have been obtained for some 40 000 stars. The Hertzsprung-Luyten-Diagram (HLD) is shown in Fig. 1. In this diagram, intrinsic magnitudes are represented by proper motion absolute magnitudes $M_\mu$. They are related to the absolute magnitudes $M$ by $M_\mu = m + 5\log\mu + 5 = M + 5\log T - 3.379$, where $T$ is the tangential velocity in km/s.

In addition to color measurements, very low-dispersion (245 nm/mm) objective prism plates are available. So far, 1 300 M stars have been classified, while spectral data for more than another 30 000 are partially reduced. From our objective prism work we found that the space density of M dwarfs as a function of distance from the galactic plane up to $z=150$ pc is on average larger by a factor 1.8 than suggested in the Bahcall-Soneira model. Also apparent is the somewhat steeper decline of space densities with distance from the galactic plane.

The fact that less than 2000 known flare stars have been registered so far (Tsvetkova et al. 1995, this volume p. 121) suggests that one might use the above methods to search our catalogs for potential flare candidates.

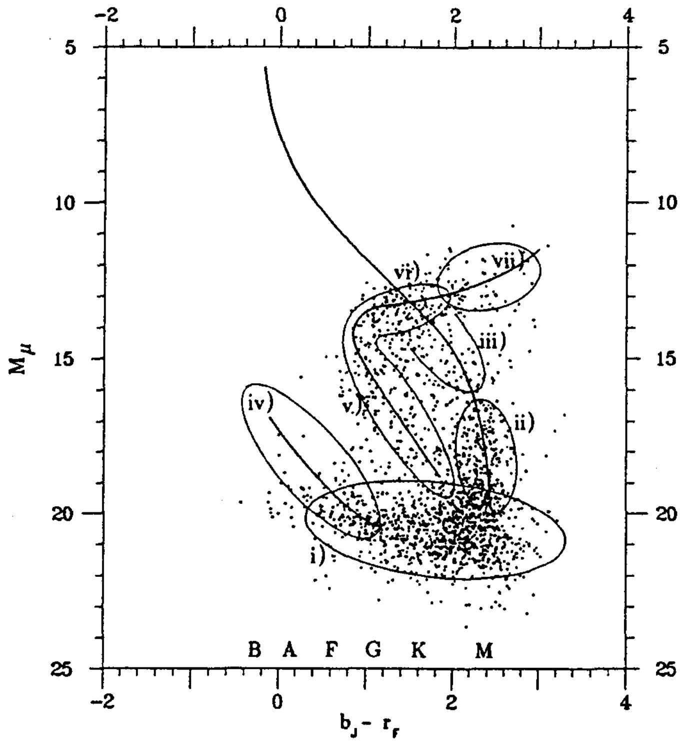


**Fig. 1.** The location of major spectral types and luminosity classes in the HLD: i = artefacts, ii = M dwarfs, iii = G and K dwarfs, iv = white dwarfs, v = G and K metal-poor stars, vi = halo G and K giants, vii = halo M giants.

## Samus: The future of the General Catalog of Variable Stars (GCVS)

I would like to give a brief contribution regarding future work on the GCVS. Financial support through IAU commission 27 is still available, and this support was unanimously expressed at the IAU this year. The fifth and final volume of the GCVS (4th edition), devoted to extragalactic variables and supernovae, is now at the printers, will appear this winter, and will be distributed in the normal way to the users. The next step is a supplement to the Catalogue of Suspected Variables: it is practically ready, and we shall look through all the material once again this spring. I don't know exactly what will follow. I am not sure we are going to print a booklet. It is rather expensive to distribute the book, but at least we will make this catalog available to the users in electronic form. In the present situation with new variables and with the approaching *HIPPARCOS* wave of information one of the most important fields of our activity will be the namelist of variable stars. All the variables should be named, so that you will not confuse them with already known variables. This work will be continued. The *HIPPARCOS* team expressed their wish and the IAU expressed their wish that variables should be designated before their material is published. If they really give us an idea which their variables are, we will try to do that. But it is a tremendous job, but we are going to publish the 72nd namelist in about one month (IBVS 4140, January 2, 1995).

The magnetic tape version of what I would call version 4.1 of the GCVS is now available. There are some mistakes which are to be corrected, and then we are going to start with version 4.2, where we are going to introduce more serious corrections. The classification system is now rather obsolete, I must admit. We must introduce new ephemerides for periodic variables, which is also necessary for users. We have all that stuff not available in datacenters (remarks, reference list), which has to be added and it will be also available to the users. Another direction of our work is work on coordinates. We undertake the serious effort to identify variable stars with positional catalogs and guide star catalogs. Our first attempt to do it automatically showed that all automatic identifications are 80% wrong, and so it has to be done by checking everything on the screen. We also have the necessary visualisation software, and an enthusiastic young man is now trying to work through it. He is very active and good, and he has done several thousand stars in two months.

The next possibility of our work: we have a database in form of a card catalog, and we have started work on a computerized database of the GCVS. Unfortunately, because the volume of information in our card catalog is large, and we do not have enough staff and enough time to do this. We fear that the software we have for this work is not quite adequate, and we lose time when we work with it. Although we have the first version, and can use it inside the group, it is insufficient now in its completeness and scope to be presented to users. I don't know what the future of this work will be: it strongly depends on the future of our institute, which is also not quite clear.

The last point is the funding. The group working on the GCVS is presently funded by Russian astronomical institutions. Compared to other astronomical groups that means "very poorly". We are very grateful to several international organisations, who gave us grants in the recent year. We had the grant of the ESO. We had a small but very necessary grant from the AAVSO which was used for the least paid members of our group. And then we have now applied for a grant of the Russian foundation for fundamental research and I hope we will get it. It will give us a possibility to continue all this work at normal scale. I am not pessimistic, though I am not quite optimistic.

**Zinnecker: Flare and flash terminology**

I would like to bring up the definition of terminologies. During this conference, I heard about flares, flashes, flickering, transients, bursts, events, and there are even subspecifications like surface flares (*e.g.* on WTTS), accretion flares (on CTTS), outbursts (on novae), eruptions (of fuors), explosions (of supernovae), explosive transients, and even echos (of jets). I think that it might be useful to define what we mean.

Shouldn't we try to adopt a more coherent classification which could be physical, according to timescales, or according to the amplitudes of these "events". I

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wanted to at least propose to define some nomenclature. Concerning the flares and flashes, which is the title of our conference, I was surprised that none of the speakers of the first day had attempted to even define for us what flares and flashes were. I start from an intuitive point of view: a flare for me is something that rises very quickly, but I do not care how it declines, whereas a flash is something that rises quickly and comes down quickly. I do not know whether it has to be repetitive or periodic. Dr. Poveda told me the difference between flares and flashes: a flare is on a dMe star and a flash – introduced by Haro – is a flare on a star in an aggregate, or cluster. So flares and flashes are the essentially same: it is just the location that determines the terminology. So that is the right definition.

We should talk about this, and whether we accept it. In any case, it also raises the question of whether the above mentioned terminology should be according to the timescales of rise and decline, or in terms of the amplitude, or in terms of physics.

### Duerbeck: Flare and flash terminology

Hans and I have briefly discussed this problem. I think the work of a good astronomer is to convert terminology of variable star activity into the physics of the phenomenon, and of course, there are a lot of phenomena known.

In the variable star catalog, we also see some problems of terminology: We have the cataclysmic variables (C) and the eruptive variables (E), and the difference is at times very difficult to define. Some eruptive variables indeed show eruptions (CTTS), others show flares (WTTS), others show outbursts (FUORS). Consider the cataclysmic variables: 'dwarf nova eruptions'. The instability which is the physical reason of variability in dwarf novae is very similar, maybe related, to the instability in accreting pre main-sequence stars. Then you can connect cataclysmic and eruptive variables in the variable star catalogs. Either one has to say 'dwarf nova outbursts' are not real outbursts like those of novae, they are 'dwarf nova eruptions' instead. But I do not know if one can reshape our terminology if we have a (hopefully) better theory to explain the phenomena.

I have written down here for example the known physical reasons for these varabilities:

| GCVS class | Terminology | GCVS Var. type or other | physics of phenomenon |
|---|---|---|---|
| C | Explosion | SN | gravitational collapse / bounce |
| C | Burst | neutron star | explosive TN burning |
| C | Outburst | N | TNR in outer layer of star |
| C | Outburst | UG | Disk instability |
| E | Flare | late type star | magnetic activity in outer layer |
| C | Flickering | catacl. var. | activity in inner accretion disk (magnetic?) |
| E | Eruption | pre-MS-star | disc changes, $\dot{M}$ |
| ? | Flash | | |

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If the physical processes are unknown, some neutral word, for example transient, should be used because the source is at some time there and at another it isn't (or it is weak), *e.g.* a gamma-optical transient. I think a fast transient can be termed flash, but of course we have to properly define the timescale: what is "fast"? I leave this question open.

**Poveda: The original definitions of 'flare' and 'flash'**

When I came to this meeting "Flares and flashes", I thought the definition was very clear. For quite a number of years flash stars have been identified with those young stars in clusters, that have some sort of flare activity. When Haro first discovered this kind of outburst in stars in Orion, he introduced the term flash star to distinguish from the flare stars of UV Ceti type in the solar vicinity, to avoid any possible confusion between the two types of activities. With the passage of time, evidence has been growing that this activity in young stars in Orion, in the Pleiades, in the Hyades is similar to the activity of UV Ceti stars in the solar vicinity. Nevertheless a few years ago, I remembered that George Herbig expressed the concern that one should pay more attention to the differences between UV Ceti activity and flash activity in young clusters. In the paper I presented I presented some evidence that the UV Ceti stars in the solar vicinity have the same kinematics as some galactic clusters. It appears that some of the UV Ceti stars are members of superclusters: the Hyades or Pleiades supercluster. It appears, although it needs more evidence, that the UV Ceti stars in solar vicinity are just the oldest members of the flare population of galactic clusters that have been broken down long ago. We cannot recognize most of them, some of them we recognize, and this may be the evolutionary, the cosmogonic relation between one group and the other. However, for the time being it would be a good idea to keep separate names for those activities in galactic clusters from the activity in the solar vicinity.

**van Paradijs: Precise terminology is not necessary**

I would like to make a general point, perhaps a little bit philosophical. The meaning of words of course is only given by their users in general. As long as you do not know what the phenomenon that you are observing means in physical terms you have to base yourself on phenomenology, and it is a social phenomenon whether or not there is confusion about terms. I think your suggestion to try to make these phenomenological terms more precise by introducing timescales is extremely dangerous, because talking about a rapid rise and a slow decay clearly is a very relative thing. You see supernovae come up in a few days, and you see it go down in a couple of months: rapid rise, slow decay. And clearly a rise of a day must be considered extremly slow when you are dealing with M stars which optical magnitude increases. So either you have an understanding what is going on in a physical sense, and you do not need phenomenology anymore to worry about your semantics, or you don't know what you are talking about, for instance GRB's, but there the phenomenology is clear enough to avoid, I think, any confusion. So I think to some extent it is a non-issue.

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**Vanderspek: Summary**

I would like to thank the participants in this round-table discussion for their contributions and insights. Clearly, there are regions of overlap between the variable star observers and those looking for counterparts to GRBs. The experiments that search for counterparts to GRBs, independent of energy, have been designed to look for variability in celestial sources, and thus are "tuned" to the characteristics of "flare" and "flash" sources: these experiments may be able to contribute to the understanding of variable stars of many classes. In particular, the wide-field experiments described here should be able to provide information about the rate of rare, high-amplitude flares.

There are other areas of overlap between flare stars and GRBs which have only been touched upon briefly in this discussion by J. Greiner. When addressing the flare star topic from the GRB point of view, one would like to know answers on the following questions and unsolved problems: (1) Is it possible that flare stars are responsible for a fraction of the detected GRBs? (2) Flare star theory predicts hard X-rays as the primary emission, but no positive detections have been made to date despite first correlations of monitoring X-ray data and strong, known flare events. (3) Can a flare star make MeV photons? (4) Is there a maximum energy which a flare star can release, either optical or bolometric? Perhaps this is a situation where two seemingly unrelated phenomena truly do have a common source, and perhaps, in time, we will be able to determine the link between the two.