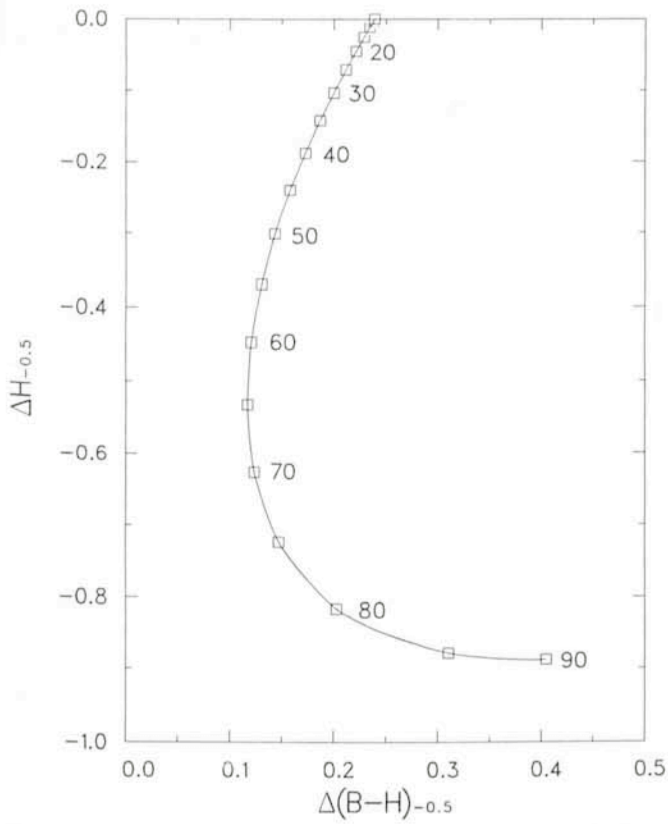

Figure 2: *Displacement in (B-H) and H due to the inclination effects at log A/D_0 = −0.5, and extrapolation of $B_{-0.5}$ from large aperture photometric data by means of mean growth curves.*

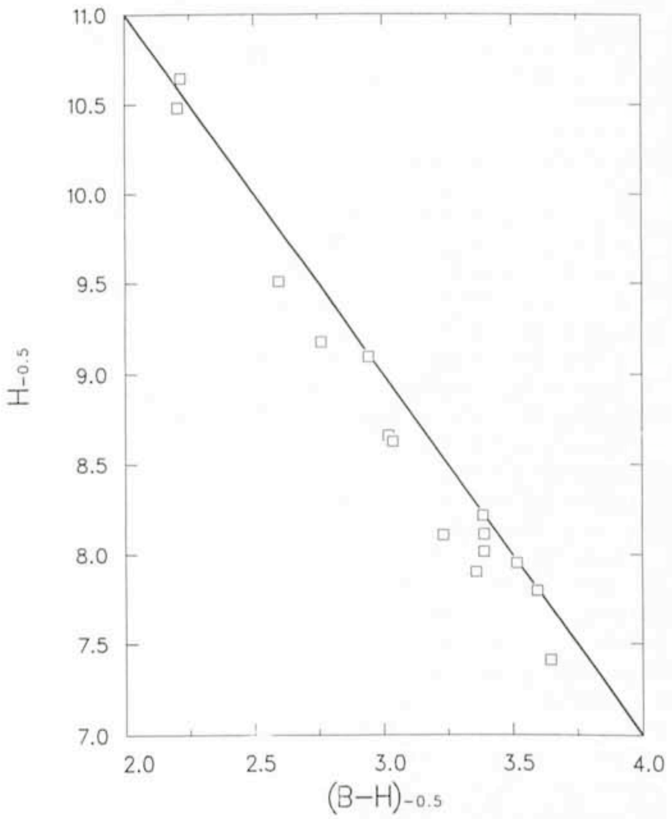

Figure 3: *Simulated $(B\text{-}H)_{-0.5}$–$H_{-0.5}$ relation for a sample of model galaxies, when no corrections for inclinations are made. Straight line shows the C-M relation from which the data has been generated.*

ing a sample of primarily face-on galaxies for observations in B and H, at apertures near log $A/D_0 = -0.5$, would seem to be a good opportunity to study the C-M relation in more detail. When at the same time one chooses to use galaxies with known redshifts, the full step of making a contribution to our further understanding of "large scale deviations from the Hubble flow" is within reach.

Thirteen nights in two runs (September/October 1987 and May/June 1988) at the ESO 1-m telescope have until now been allocated to a project, where this is the main goal. The data were acquired using a single channel photometer with the "Quantacon" in the B band, and after a change of setup to infrared in the middle of the observing period, with an infrared photometer using an InSb detector for the H band photometry. Unfortunately, very poor weather conditions were encountered during the major part of the first observing period. Useful observations under photometric conditions could be performed in B for less than 1 night and in H for 1 night so far. Since each galaxy has to be observed through a couple of apertures in each band, only observations of an uninterestingly small number of galaxies have been finished so far. Thus there is hardly enough to comment on yet. Hopefully I shall be in a better position after my next run at La Silla.

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Searching for Double Degenerates

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The Elusive Progenitors of Type I Supernovae

The majority of stars are members of binary systems; this is a frequently referred aphorism. The majority of stars also terminate their evolution as white dwarfs (WDs), as only few stars are born massive enough to experience a supernova explosion. We can easily conclude that the majority of binary systems must at some stage become a double WD binary, and that a good fraction of the stars listed in our catalogues as WDs may indeed be double.

Very few WDs, however, are known for being double, and indeed Greenstein (1986) lists just six such objects. These are very wide pairs, visual double degenerates, in which each component has evolved independently of the other, as if it were a single star. An example of this kind may be provided by the Sirius system: in less than one billion years also Sirius A will be a WD, and Sirius A+B will become a wide double degenerate (DD) system. But in *close* binaries the evolution of each component is severely affected by the presence of the companion: The system can experience common envelope phases during which first the envelope of the primary, and subsequently that of the secondary, are expelled from the system thus leaving bare, WD cores. The energy required for such an ejection is supplied (via friction) by the orbital motion of the binary: The orbit then shrinks during the common envelope stages, and at the formation of the second WD the separation can be much smaller than the original separation, when both stars were on the main sequence. This is just contrary to the evolution of wide binaries, where mass loss from the system leads to even larger final separations.

The relation between initial and final separation is theoretically very uncertain, an uncertainty which follows primarily from the hydrodynamical complexities of the common envelope stages which prevent a secure estimate of the efficiency (α) with which the orbital energy is converted into energy of the ejected envelope (Iben & Tutukov 1984). The smaller this efficiency, the closer the two WDs as the second WD is formed, i.e. the smaller the *initial* separation of the DD phase in the evolution of the binary system.

The duration of this phase, unlike the previous *nuclear* phases of stellar evolution, is controlled by a new *clock:* gravitational wave radiation. The fate of DD systems is then to spiral in, until the less massive WD fills its Roche lobe and the two components merge. If the initial semimajor axis of the DD is smaller than a critical value, then merging will occur within a time less than the Hubble time, and merging itself will become an astrophysically interesting event. Indeed, if the DD consists of two carbon and oxygen WDs and its combined mass exceeds the Chandrasekhar limit ($\sim 1.4\ M_\odot$) then either a thermonuclear explosion (carbon deflagration) destroys the star completely (Iben and Tutokov 1984), or the collapse of the merged object leads to the formation of a neutron star (Nomoto and Iben 1985), depending on the uncertain timescale of the actual merging process. Both possibilities are astrophysycally very interesting, as either a type I supernova event or a millisecond pulsar would then respectively be produced (Iben and Tutukov 1984, Saio and Nomoto 1985). The former case is perhaps more exciting, due to the strong impact that type I SNe have on the evolution of galaxies. Type I SNe, in fact, are thought to generate most of iron-peak elements produced in galactic nucleosynthesis (e.g. Greggio and Renzini 1983, Matteucci and Greggio 1986) as well as most of the heating required to maintain the interstellar medium of elliptical galaxies to the observed high temperature inferred

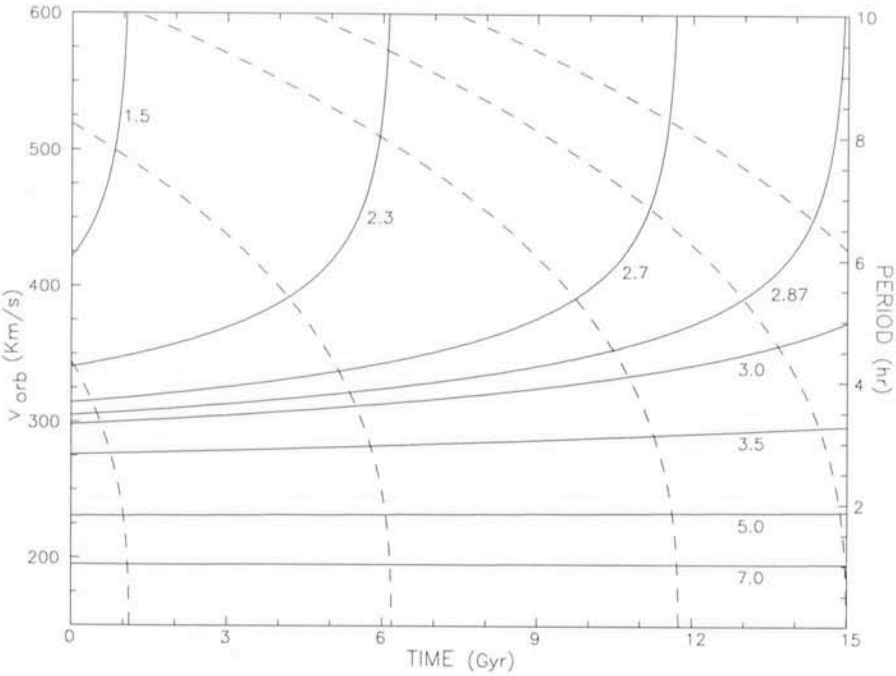

Figure 1: *The evolution of the period and orbital velocity of a double degenerate system of two $0.7\ M_\odot$ white dwarfs, as angular-momentum losses by gravitational wave radiation progressively shrink the orbit. Each curve is labelled with the initial semi-major axis in $R_\odot$ units. Note how the merging time is strongly sensitive to the initial separation of the DD system. Note also that objects with initial orbital velocity in excess of ~ 300 km s^{-1} merge in less than one Hubble time (assumed to be $\sim 15 \times 10^9$ yr).*

from their strong X-ray emission (Fabbiano 1986, Canizares et al. 1987, Loewenstein and Mattews 1987). Clearly, the understanding of important aspects of galactic evolution requires a kowledge of the rate of type I SNe over cosmological times, which in turn depends on the detailed distributions of binary parameters, like masses and separations. Still, the mentioned theoretical uncertainty in the efficiency parameter α prevents a deterministic estimate of SNI rates as a function of population age, and at this point only dedicated observations of SNI candidate progenitors could help passing beyond this bottleneck.

In this frame, we have started an observational programme aimed at reducing the uncertainties still enshrouding both the final stages of binary evolution and the nature of SNI progenitors. The questions we aimed to answer are basically two: (1) How frequent are DD systems among known white dwarfs? and (2) what is the fraction of such systems that will likely merge in less than one Hubble time? Figure 1 shows the computed evolution of the period and orbital velocity of DD components, as gravitational wave radiation progressively shrinks the orbit. One sees that the initial orbital velocity of the DD must exceed ~ 300 km s^{-1}, if merging is to take place

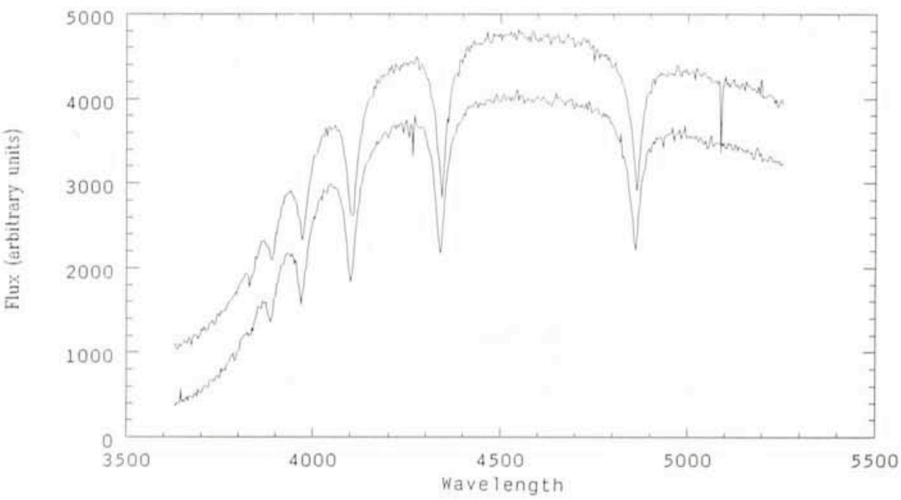

Figure 2: *Two spectra of WD-17 taken 25 hours apart. The flux scale is arbitrary. Note the shift of the Balmer lines, which corresponds to a radial velocity change of ~ 220 km s^{-1}.*

within one Hubble time. In this example, this corresponds to an initial period of ~12 hours. Therefore DD systems in which we are interested should exhibit radial velocity variations of a few hundred km s^{-1}, that can easily be detected using modern instrumentation. Correspondingly, our observational strategy has been to start a spectroscopic survey of catalogue WDs, with the aim of finding high orbital velocity DD pairs. We stress that theory cannot really predict what fraction of WDs are actually DD systems: This is in fact the main motivation for undertaking such a search, that ultimately we would like to extend to ~100 WDs, so as to ensure some statistical significance of the sample.

Hunting White Dwarf Binaries with EFOSC

Our target objects were chosen from the *Catalogue of Spectroscopically Identified White Dwarfs* of McCook and Sion (1984). The selection criteria of our choice have been very simple: We wanted the WDs to be relatively bright in order to minimize the observing time required to get a high S/N spectrum, and we further restricted to WDs of the DA variety in order to achieve the highest possible accuracy in radial velocity determinations, thanks to their prominent Balmer lines. Basically, our observational strategy has been to take several spectra of the same WD, a few hours apart (in practice, intervals between 2 and 25 hours), and then look for any radial velocity change. This should be most efficient in the case of DDs with components of very different luminosity (very different cooling time), while old DDs should rather have similar luminosity, and then exhibit variations in line profile, rather than in line position. EFOSC at the 3.6-m telescope was chosen as this provides the optimal observing configuration: thanks to its high efficiency, high S/N multiple spectra of several objects can indeed be obtained in one night. Moreover, each spectrum is obtained with a relatively short exposure (<~15 min), which then ensures adequate time resolution also in the case of short-period objects. Our observational strategy is very different from others that have been unsuccessful in singling out DD candidates that may be SN I progenitors. In particular, we are not bound only to short-period systems as in the case of the survey of Robinson and Shafter (1987).

Till now we had two observing runs at the ESO 3.6-m telescope, respectively in September 1985 (2 nights) and in January 1988 (3 nights). A total of 20 WDs have been observed at least twice and possibly three times, always using EFOSC with the B150 grism (spectral range 3600–5590 Å) giving a resolution of ~6.5 Å.

The reduction was carried out with the IHAP system in Garching. The spectra were wavelength calibrated with a helium lamp generally taken at the same telescope position of the target object. This data base allows to test the limiting accuracy of EFOSC for radial velocity determinations. By comparing the different calibration exposures taken through the night at different zenithal distances (from 1 to 2 air masses) we note that the lines fall in the same position on the CCD to within ~0.15 pixels, which would correspond to a systematic shift of ~35 km s^{-1} at λ = 5000 Å. The accuracy of the dispersion curves fitting the calibration lines of an individual exposure is somewhat better, giving an RMS of ~0.3 Å (or ~20 km s^{-1} at λ = 5000 Å). Our velocity determinations are based on several absorption lines, and hence we estimate that the error is actually smaller than 20 km s^{-1}. For the objects observed in the first run, we used a single calibration exposure taken at the beginning of the night. This leads to a larger uncertainty in the velocity determinations for the first run objects, that we then estimate to be at least of the order of ~60 km s^{-1}.

Given the main goal of the project, we are primarily interested in the actual value of the v_r differences between two or more spectra of the same star, taken at different times. To get such differences, we use a programme whose original version had been written by Pier (1983) and which has been adapted to work on WDs, where generally lines are very broad so that the wings are very important. The programme uses one spectrum as template; after normalizing, flattening with continuum subtraction, and rebinning, the programme computes the cross-correlation of this template with a second spectrum of the same star. The position of the cross-correlation peak gives immediately the velocity difference between the two spectra.

Two Good Candidates and Two WDs with Red Dwarf Companions

We have determined v_r variations for the 20 programme stars for which we have at least two spectra. Among these WDs two turned out to have red dwarf (RD) companions, and these two interesting objects are discussed below. Of the 18 residual dwarfs 9 were observed in the first run, and 9 in the second. All the first run objects show Δv_r values between ~50 and ~150 km s^{-1}, just consistent with all being the result of our poorer accuracy during that run. The situation is far more exciting for the second run objects: here seven dwarfs exhibit Δv_r consistent with 1σ errors ~20 km s^{-1}, one WD has $\Delta v_r \simeq$ 70 km s^{-1}, and for the last dwarf (WD-17, in our list of targets) the cross corre-

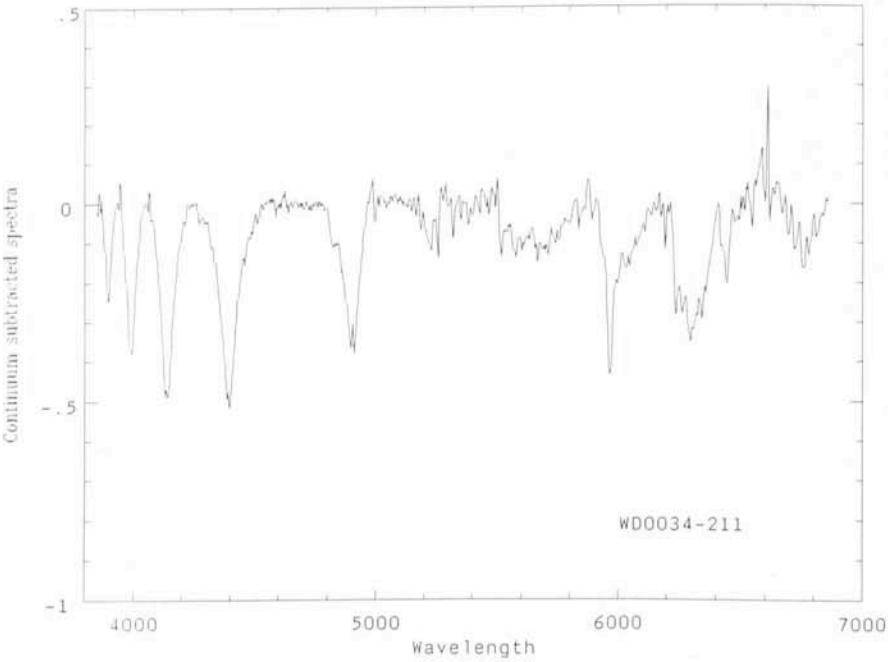

Figure 3: *Continuum subtracted and flattened spectrum of WD 0034-211; this is a composition of one blue and one red spectrum, taken respectively with the B 150 and O 150 grisms. Shortward of ~5000 Å the WD component dominates the light, while the red companion dominates at longer wavelengths. The faint emission core in the Balmer lines suggests the presence of an accretion disk. In the red side of the spectrum the most prominent features are the narrow Na absorption, several TiO bands, and the strong Hα emission.*

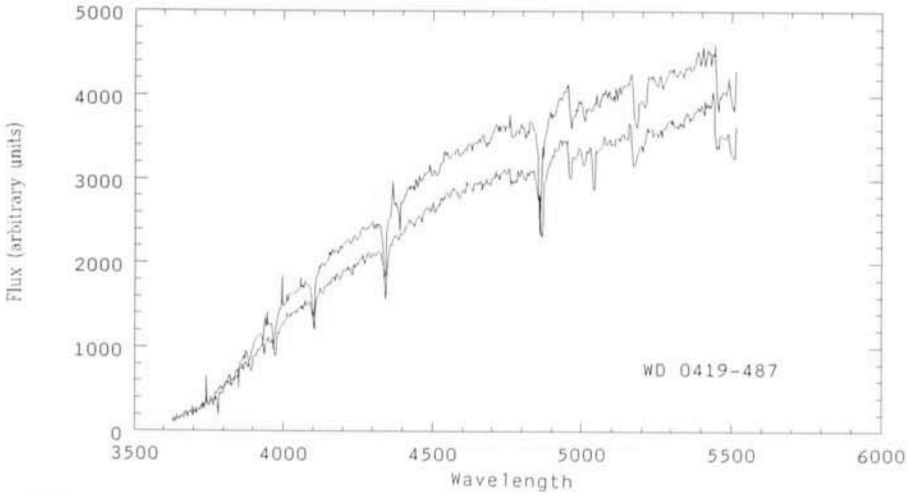

Figure 4: *The blue spectrum of WD 0419-487; note that also in this case the lines of the red companion are prominent in the red side of the spectrum. The Balmer lines are much narrower than in the case of the two other WDs; this is indeed a low surface gravity WD with a mass of only ~0.29 $M_\odot$.*

lation between the three available pair of spectra gives Δv_r = 220, 176, and 45 km s^{-1} respectively, well above our estimated errors. Figure 2 shows two spectra of WD-17, where the shift in line position is also apparent. We conclude that two new DD systems may have been discovered, one of which exhibits radial velocity changes which are interestingly close to those expected for SN I progenitors. Clearly, further observations are required to confirm these preliminary results, and to determine the full Δv_r amplitude and period of the two DD candidates.

We now turn to the dwarfs with composite spectra. The spectrum of two programme WDs showed in fact clear signs for the presence of a RD companion. These two WDs were indeed already listed by Probst and O'Connell (1982) among the seven WD+RD pairs that they have discovered photometrically, thanks to their IR excess. The inclusion of these two objects in our programme was however unbiased, and then we can refer to a spectroscopic *rediscovery* of their binary nature. This will be relevant for the statistical aspects of the present research. In any event, the spectroscopic study of the two pairs is revealing some very interesting properties of the systems.

In one of them (WD0034-211, observed in the first run) a faint emission core was evident in all the Balmer lines, possibly indicative of an accretion disk originated by transfer of material from a nearby companion. In the second run we have then reobserved this object in the red spectral range (5000–7000 Å), using the O150 grism and calibrating with the He+Ar lamp. The composite spectrum (from 3600 to 7000 Å) is shown in Figure 3: Note the presence of several TiO bands typical of M-type stars, as well as the prominent Hα emission. The two blue spectra that are available do not indicate an interesting change in the radial velocity. However, the Balmer emission suggests that the RD component may be filling its Roche lobe, in which case the system should be very close. Orbital shrinking by both a common envelope stage and subsequent gravitational wave radiation might be blamed for the present configuration of the system, which appears to have the characteristics expected for a cataclismic binary caught in quiescence.

The other WD+RD pair (WD0419-487) is also an exciting object. Its spectrum is shown in Figure 4, where TiO bands are also evident at longer wavelengths where the RD light dominates. We have then applied the cross correlation technique separately for the blue (3850–4650 Å) and yellow parts of the spectrum (5000–5500 Å), so as to obtain the Δv_r of the WD and of the RD, respectively. This gives Δv_r = −124 km s^{-1}, and +232 km s^{-1}, indicating that the mass ratio is close to 0.53. Since the mass of the WD primary is known from surface gravity determinations to be ~0.29 $M_\odot$ (Koester et al. 1979), we can then estimate the mass of the RD secondary as ~0.15 $M_\odot$. The system appears to have evolved through a Case B Roche-lobe overflow, when the primary was experiencing its red giant phase of evolution, with a 0.29 $M_\odot$ helium core. We can then guess the approximate dimensions of the original orbit, and when knowing the present dimensions we could obtain a lower bound to the crucial efficiency parameter α.

Two very important applications of the WD+RD pairs can then be anticipated: First, we can check the mass-luminosity relation for RDs, which theoretically is extremely uncertain (cf. Liebert & Probst 1987, Renzini & Fusi Pecci 1988) while its knowledge is fundamental for the derivation of the low end of the initial mass function, and then for assessing the baryonic contribution to dark matter. Second, the determination of the masses and separation of WD+RD pairs can help setting constraints on the dynamical parameter α, and then help a better understanding of binary evolution, with implications also for the DD systems that may lead to a supernova explosion, and in which we are most interested.

The Perspectives

Our spectroscopic study of WDs has so far singled out four very interesting objects: The two WD+RD pairs and the two WDs with large radial velocity differences. This is quite a high proportion when we consider that just 20 objects have been investigated so far. The natural developments of this project are then both extensive as well as intensive: On the one hand we need in fact to enlarge the sample of observed WDs, on the other hand, we would like to obtain further data for those systems which are found to exhibit special characteristics. For example, we need to determine spectroscopic periods, as well as whole radial velocity curves. In particular, the system WD-17 deserves further study. Its large radial velocity variation makes it the best DD candidate for a SN I progenitor, comparable to WD0135-052 whose DD nature had been anticipated by Greenstein (1986) and spectroscopically confirmed by Saffer et al. (1987). In conclusion, modern instrumentation and techniques allow a fresh approach to apparently unconspicuous objects such as white and red dwarfs. Although certainly all WDs had a bright past, most will just fade away as time goes by. Few among them, however, might have an explosive future. Time is ripe for a closer look on these dwarfs.

Acknowledgements

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A Search for Flare Stars With the GPO Astrograph

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1. Flare Stars in Young Stellar Aggregates

The first systematic investigation of flare stars by the Mexican astronomer Guillermo Haro marks the beginning of long-term, multi-site studies of these objects in young stellar aggregates. His first series of observations with the Schmidt telescope of the Tonantzintla Observatory already showed the close relation between stars in the T Tauri stage and cool dwarf stars with enhanced UV activity (= flare stars), both types of objects being still in their early stages of evolution.

After 30 years of subsequent investigations, some of the conclusions by Haro are substantiated on the basis of extensive observational material, while the new results also gave a clearer picture of the nature of flare stars. Some of the main achievements and results to be substantiated by further studies are:

- More than 1,000 flare stars in the aggregates of Orion, the Pleiades, NGC 7000 (North America nebula), Praesepe, Coma, and others were discovered.
- The physical correspondents of flare stars in aggregates are the UV Ceti stars in the solar neighbourhood.
- By observing multiple flares in given stars, the lower limit of the number of flare stars in various aggregates could be estimated: Orion – 1,500; Pleiades – 1,000, NGC 7000 – 400, Praesepe – 300, Coma – 100 stars.
- It was found that, for a given aggregate, the spectral type of the brightest flare star and the maximum flare amplitude both correlate with the age of the aggregate.
- In stellar evolution, the T Tauri stage is followed by the flare star stage.
- There are two major types of flares, fast and slow ones. It is concluded that all flares have the same physical origin, since there are also rare flares of intermediate speed.

The close correspondence between flare stars in aggregates and in the solar vicinity, as well as some analogy between the flares in these stars and the solar flares suggest theoretical models for the underlying physical process(es). However, a general picture which includes all aspects of the problem of correlating the properties of flare stars, UV Ceti stars and older main sequence stars, has not yet been developed.

2. The GPO Astrograph

The GPO astrograph was one of the first telescopes on La Silla. At its previous location Zeekoegat in South Africa (1961–1966) and during its first years on La Silla, it was mainly used to obtain objective prism spectra of stars in the direction towards the Magellanic Clouds. One of the rare spectra of Sk – 69° 202, the star that later became SN 1987A, was taken with this instrument.

A new chapter for the GPO was opened with increasing interest in direct plates. Most of them are used for *astrometric* purposes: for asteroid observations, proper motion studies, and for the input catalogue of the HIPPARCOS astrometric satellite mission. Recent highlights of the southern sky, Halley's Comet and the Supernova 1987A, tempted more observers to "try" the GPO. We will report on one of our two *photometric* surveys, the search for flare stars with the GPO. Figure 1 displays the observational activity of the last two decades.

3. The Suitability of the GPO for a Flare Star Search

Until now, patrol observations of flare star fields were predominantly carried out with Schmidt telescopes in the northern hemisphere. The Schmidt telescopes in the southern hemisphere were to a large extent occupied by atlas

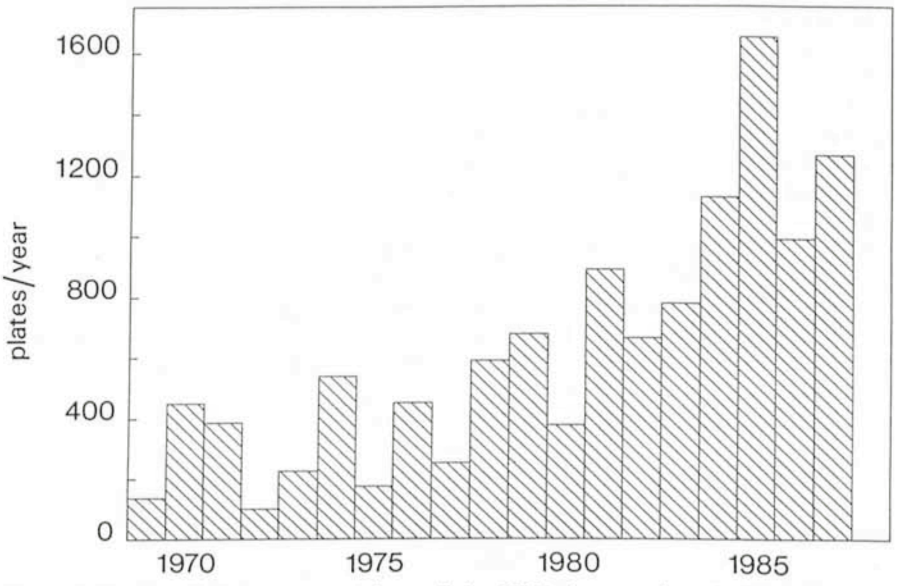

Figure 1: *Number of plates per year taken with the GPO telescope since the beginning of its operation on La Silla.*