The Discovery of a New SU UMa Star

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For the observing run in November/December 1980 at La Silla, R. Schoembs and myself had a strict observing schedule long before travelling to Chile in order to make best use of the allotted instruments. A usual behaviour common to all astronomers, I think. But a lucky chance made us change our plans in some details on the spot: We discovered a new member of the SU UMa subgroup of dwarf novae.

It's my aim to tell some of the exciting circumstances of that discovery and to report some results of the measurements of the new SU UMa object TU Men.

Dwarf Novae, a Subgroup of Cataclysmic Variables

Dwarf novae belong to one of the four subgroups of the cataclysmic variables. The denotation *cataclysmic* originates from the ancient Greek word κατακλυσμόσ which means catastrophe or deluge. This describes the main property of these objects to erupt with more or less catastrophic consequences for the whole system. According to a generally accepted model a cataclysmic variable consists of a very close binary system. The primary component is a white dwarf surrounded by a disk of matter of low density. The companion is very similar to a red main-sequence star. Both circulate on their orbits with rather short periods, mostly within the range of 1–10 hours with an empty gap between 2–3 hours. This remarkable period gap is of great importance from the point of view of stellar evolution (see H. Ritter, 1980, *The Messenger* No. 21, p. 16). There is a mass flow from the red secondary towards the white dwarf. Where that stream impacts the accretion disk the material heats up and a bright hot spot is produced. (Figure 2 in the article of H. Ritter presents a beautiful picture of the model of a cataclysmic variable.)

Caused by some unknown mechanism dwarf novae suddenly erupt from time to time. Then the brightness of the system increases within hours by a factor of 100 and the spectrum mainly changes from an emission-line to an absorption-line spectrum. Such an outburst lasts about a few days and repeats in the order of weeks.

This short and rough presentation of the scenario of a dwarf nova system cannot compensate for an exact description of the theoretical model and all of its characteristics. More details are given for example in the review article of E. L. Robinson (1976, *Annual Review of Astronomy and Astrophysics,* Vol. **14,** p. 119) or B. Warner (1976, IAU Symp. No. 73, p. 85).

SU UMa Stars, a Subgroup of Dwarf Novae

The research on cataclysmic variables has got new aspects during the last years due to the discovery of the so-called SU UMa stars. These objects have additional striking properties compared with normal dwarf novae. For example, a second kind of outbursts occurs. These eruptions are called super-outbursts because they last much longer than the normal ones and the maximal brightness exceeds that of a short outburst. The recurrence time is of the order of months and so much longer than that of normal maxima. The most puzzling property, however, is the superhump-phenomenon. In the course of a super-outburst a periodic feature in the light-curve—the superhump—appears, which does not repeat with the orbital period measured spectroscopically for example. The superhump period P_s is always longer than the orbital one by a few per cent. The understanding of that phenomenon, observed for SU UMa stars during super-outbursts only, is not satisfactory as yet. One of the most recent models explaining the observational facts of SU UMa objects is presented by N. Vogt (1981, ESO preprint No. 138) who assumes an eccentric disk around the white dwarf formed during a supermaximum. For more details dealing with models and observational facts I have to refer to this work or to a review article of N. Vogt (1981, *Astronomy and Astrophysics,* Vol. **88,** p. 66).

TU Men, a Possible SU UMa Candidate

For the observing run in November/December 1980 on La Silla, checks for outbursts of more or less unknown dwarf novae had been planned as a supplement of the main programme. During the preparation at home, I had paid special attention to possible SU UMa candidates. One of those objects was TU Men, a faint dwarf nova (brightness $m_v \geq 16^m$). During 1963 and 1978 TU Men had been observed in many nights by several members of the variable star section of New Zealand. On these observations F. M. Bateson (1979, Publ. Var. Star Sect., Roy. Astron. Soc. New Zealand **7,** p. 5) based his assumption that two groups of outbursts could be distinguished: Faint eruptions ($m \simeq 13^m.5$), which last approximately 1 day and recur every 37^d, and bright eruptions ($m \simeq 12^m.5$), which last 4–20 days recurring every 194 days. TU Men therefore seemed to possess two characteristics of SU UMa stars and had been included in the observing programme.

At the end of the first observing night on La Silla we had a look at TU Men and found the star in a state of outburst. Because of that new situation we rearranged the time schedule and decided to observe TU Men photometrically in the second night from the beginning.

TU Men, a New SU UMa Object

To our great surprise the brightness of TU Men seemed to increase immediately after starting the measurement. Checking the electronic equipment and the intensity of the comparison star we convinced ourselves that this variation was real. A few minutes later the brightness decreased again to reach a constant level. In that moment we suspected for the first time a super-outburst for TU Men and the evidence of a superhump phenomenon. To confirm that, we had to measure several superhumps and we expected the next one at the latest about 2 hours after the first one. This assumption was based on the fact that all SU UMa stars already known belonged to the ultra-short-period cataclysmic binaries with periods below the well-known gap between 2 and 3 hours. But the chart recorder continued to display constant brightness even 2 hours after the first one! Thirty minutes later we were almost completely disappointed when finally the rise to the second superhump took place! At the end of that night we had recorded 3 superhumps of TU Men recurring with a period of about 3 hours! Following the rule that the orbital period P_0 and P_s differ by a few per cent only, the long superhump period of TU Men indicated that SU UMa objects could be found even beyond the period gap. To verify this assumption, besides an accurate photometry of TU Men it was important to determine the orbital period by means of spectroscopic observations. So TU Men had changed from a substitute to the main object in one night.

Photometric Observations of TU Men

The lightcurve recorded during a time interval of 16 days is shown in Figure 1. The measurements have been obtained with the 50-cm Danish, the 62-cm Bochum, the 1-m ESO and the 1.5-m Danish telescopes. The lightcurve shows the periodic superhump phenomenon. The amplitude of the variations decreases from $\Delta m = 0^{m}.36$ during the first two nights to $\Delta m = 0^{m}.13$ at the end of the observations.

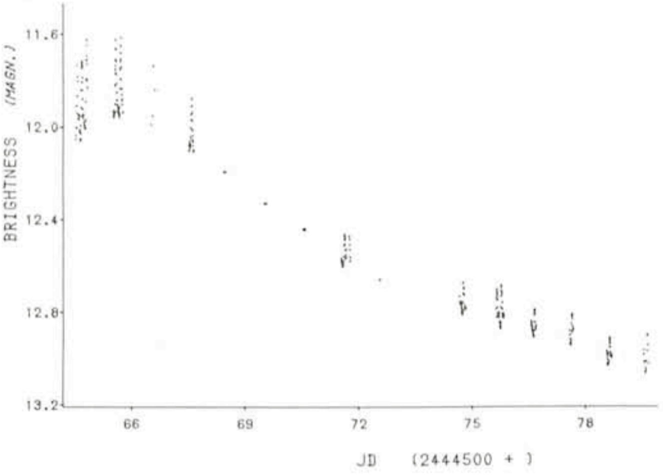

Fig. 1: *Lightcurve of TU Men over the whole observing run (1980, Nov. 20 – Dec. 6).*

The superhump timings cannot be described by a constant period. With a period P determined from the first two nights, one gets a phase shift reaching 1.4P for the last recorded superhump. So, as in the case of other SU UMa stars, a linearly decreasing period has been adopted for the superhumps. A least-square fit to the observed timings of maximal brightness yields the following ephemerides:

$$HJD = 2444564.584 + .1262\,E - 6 \times 10^{-6} E^2.$$

Spectroscopy of TU Men

The spectroscopy of TU Men has been performed in 4 nights at the 1.5-m ESO telescope equipped with the IDS.

All 42 spectra show the typical very broad Balmer absorption lines of dwarf novae during outburst. A sine curve has been fitted to the mean velocities of each spectrum. The minimum of rms-error is obtained for the period

$$P_o = 2.820 \text{ hours} = 0^{d}.1176 \pm 0^{d}.0007$$

Figure 2 shows the resulting phase diagram. The result indeed confirms the assumption that SU UMa stars are not restricted to the ultra-short-period cataclysmic binaries below the period gap.

The $P_s \leftrightarrow P_o$ Relation

Including TU Men and WZ Sge, orbital and superhump periods are known for 7 objects. (Because normal outbursts fail to appear, WZ Sge is not a SU UMa star in the common sense. Nevertheless, a superhump phenomenon has been detected for that system. See J. Patterson et al., 1981 *Astrophys. J.* Vol. **248**, p. 1067.) With these data a relation between P_o and P_s can be established. This has been done in Figure 3, which shows $(P_s-P_o)/P_o$ versus P_s. The points are well fitted by a parabola; this is probably due to the small number of points used; however, if this relation is supposed to be correct, it allows to compute the orbital periods for SU UMa objects of known P_s.

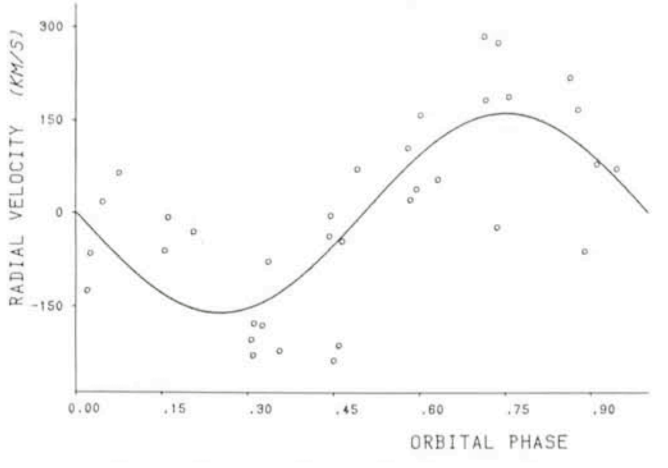

Fig. 2: *Radial velocity curve of TU Men obtained during the superoutburst in December 1980.*

One consequence of the observations of TU Men and the derived relation between P_s and P_o is that the period gap of CV's shrinks to forty minutes: On one side there is the observed orbital period $P_o \simeq 2^h50^m$ of TU Men, on the other side the computed period $P_o \simeq 2^h10^m$ of YZ Cnc.

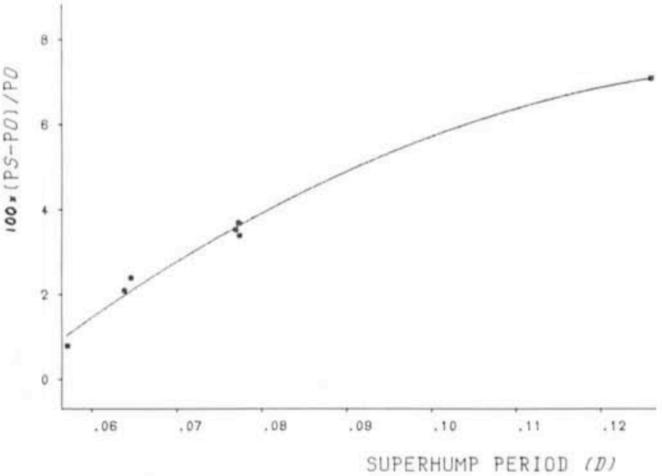

Fig. 3: *$(P_s-P_o)/P_o$ versus P_o for seven objects with known orbital and superhump period.*

I hope that this report has given an impression of our work on dwarf novae, especially on SU UMa stars and an idea of our exciting experiences during the night when TU Men was discovered to be a member of that subgroup of CV's. For me it was the first time on La Silla and I never believed in having such good luck to receive so many data from such an interesting object.

Last not least we want to express our thanks to all staff members and night assistants, especially Dr. H. Pedersen and J. Veliz.