fig. 1, D. Baade has plotted our observations of HR 2142 (phase 0.5 corresponds to the primary shell phase) and shows that there is no modulation of the light curve with phase of the orbital period. Unfortunately the short shell phases (spanning less than 8 days) were missed twice as they fell outside the observing times. A more fortunate coincidence between shell phase and observing time will teach us more about the photometric activity during that phase. Fig. 1 also shows that the brightness of the star was essentially constant for most of the time, but on two different levels. Only from future long-term monitoring of this star can we learn if this $0\overset{m}{.}13$ decrease in all passbands is related to certain phases of the orbital period or if other periodicities are present.

Another highlight is undoubtedly the discovery of an S Dor-type outburst in the Of star R127 (See Wolf & Stahl's article in this issue of the *Messenger)*. A remarkable result is also the discovery of the binary nature of the luminous LMC supergiant R81. By combining older photometric data with data obtained by various observers in our project, F. Zickgraf (Landessternwarte Heidelberg) found a period of 29.18 days. Fig. 2 shows the average light curve. The residual scatter is larger than expected from the photometric accuracy, but this is due to intrinsic variability of the supergiant. The shape of the light curve indicates that R81 is probably an eclipsing contact binary. The star will be given highest priority during the September and December 1983 observing runs.

Besides the direct scientific results, the programme offers several attractive aspects. Young observers who have not established their own field of research may join one of the teams of our group, in that way they will acquire experience in

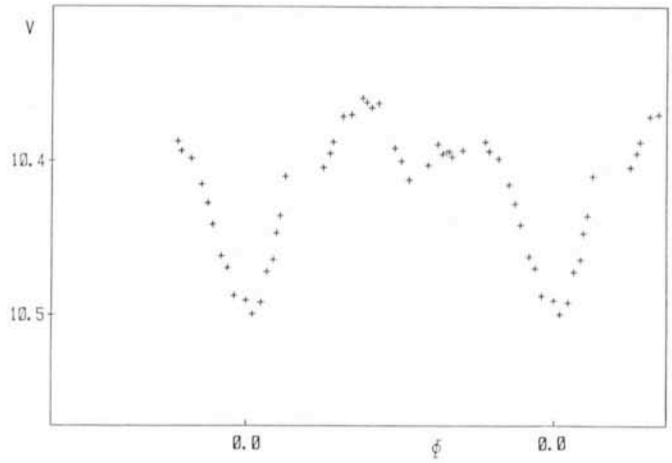

Fig. 2: *Average V-light curve of R81 constructed with a period of 29.18 days.*

different fields of variable star work. The project definitely stimulates international collaboration, especially for what concerns events of opportunity (e.g. simultaneous coverage with other ground-based or space observations).

There is also a close collaboration with Dr. J. Maza (Universidad de Chile) regarding information about events such as bright galactic novae.

The actual group consists of 22 participants. We do hope that more people from different countries will join the project.

Discovery of an S Dor Type Outburst of an Of Star at La Silla

B. Wolf and O. Stahl, Landessternwarte Heidelberg

What are S Dor Variables?

Back in 1897, E.C. Pickering reported on the variable star S Dor in the Large Magellanic Cloud (LMC). A quarter of a century later, J.C. Duncan (1922) and M. Wolf (1923) independently discovered a few variable stars in M 33. Since the extragalactic nature of these galaxies was not yet established in those days (i.e. their distances were not known) these authors could not realize that they had discovered some of the most luminous variables of the Universe with absolute visual

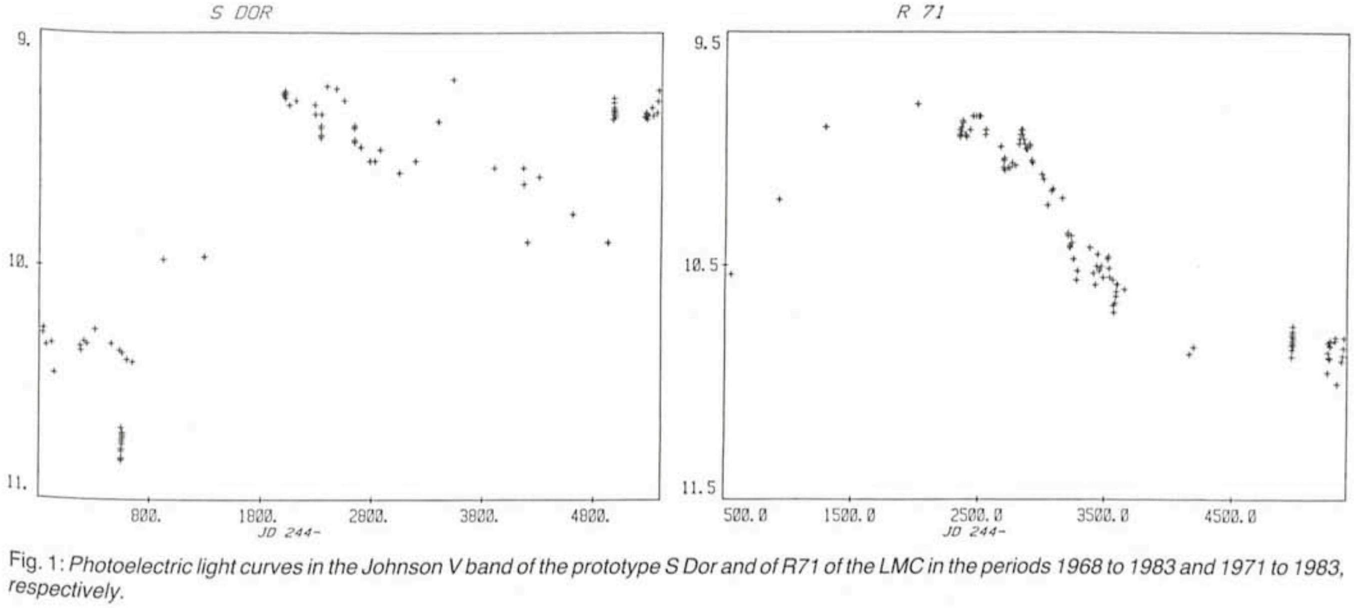

Fig. 1: *Photoelectric light curves in the Johnson V band of the prototype S Dor and of R71 of the LMC in the periods 1968 to 1983 and 1971 to 1983, respectively.*

magnitudes brighter than $M_v \approx -9$. Thirty years later, in 1953, Hubble and Sandage investigated these stars, nowadays called Hubble-Sandage variables or S Dor variables, in more detail. Their main characteristics are: (1) extremely high luminosity ($L \approx 10^6 L_\odot$), (2) spectral types: early B to F, (3) strong ultraviolet excess ($U-B \lesssim -0.8$) and infrared excess, and (4) variations of more than one magnitude in the visual spectral range on timescales of years to decades.

As will be shown below, the S Dor variables and related objects have recently gained considerable interest as a possible missing link in the evolution of very massive stars with stellar masses $M \gtrsim 50 M_\odot$. S Dor variables are also known to exist in the Galaxy. For instance, we have recently confirmed (Wolf and Stahl, 1982) that AG Car belongs to this class, and the enigmatic star ηCar has long been known to be at least related to this group.

Since the S Dor variables of the LMC are on the one hand comparatively bright ($V \approx 9$ to 11 mag) and their distances are on the other hand quite well known, our group has been particularly engaged in investigating these stars. It turned out that the combination of spectroscopy and photometry and the simultaneous observations in different wavelength regions (from UV to infrared) provide particularly interesting results.

Earlier Ground-based and IUE Observations of S Dor Variables in the LMC

One of the main characteristics of the S Dor variables is their light variability on timescales of years to decades. (Variations on shorter timescales [hours or days] are known, but these are of small amplitude.) In fig. 1 the light curves of the two

Fig. 2: *Section of coudé spectrograms (12 Å mm⁻¹) of S Dor during maximum taken with the 1.5 m spectroscopic ESO telescope. Note the pronounced P Cygni-type profiles of singly ionized metals and the considerable profile variations.*

established S Dor variables of the LMC (R71 = HDE 269006 and the prototype S Dor) are presented. The data were compiled from many sources in the literature and supplemented by our own measurements collected at La Silla.

It has long been known that S Dor variables are bluer during minimum by about 0.2 mag in B-V than during maximum. It was suggested earlier that the considerable brightness and colour variations are due to the ejection of massive envelopes during outburst. In fact the mass loss rates of S Dor variables during outburst are of the order of 5 to $10 \cdot 10^{-5}\ M_{\odot} yr^{-1}$, i.e. about a factor of ten higher than the rates found for "normal" hot stars. The strong mass loss is evidenced by the appearance of P Cygni-type profiles of singly ionized metals during maximum. Practically all lines are of P Cygni type indicating that the underlying photospheric spectrum is completely masked by the envelope. A sequence of spectra taken during a time interval of four years during the recent maximum of S Dor is shown in fig. 2. Considerable line profile variations are evident indicating that the mass loss mechanism differs from the one working in "normal" luminous stars. In addition, it is found from the spectra of S Dor variables that their winds are comparatively cool and that the mean expansion velocities are comparatively low (60–150 km s^{-1}). These low velocities are also shown by the recently obtained IUE high dispersion spectrum of S Dor. A section of this spectrogram is shown in fig. 3. In all cases where we investigated the spectra of S Dor variables in more detail, we found the wind to be decelerated outwards – also in contrast to the behaviour of normal hot stars. The strong UV- and IR excesses during outburst are a consequence of these wind characteristics. Fig. 4 shows that the mass loss of S Dor variables (and of related post-main-sequence envelope objects) is considerably higher than that of normal luminous stars.

We note that the spectra of S Dor variables during minimum show a rather normal early-type absorption spectrum often with superimposed forbidden Fe II lines or other forbidden lines, due to the diluted relics of the matter expelled during outburst. A good example showing the differences between the minimum and maximum spectrum was given by Appenzeller, Stahl and Wolf in the *Messenger* No. 25, Sept. 1981. We have concluded that S Dor variables are supergiants (hotter than previously thought) in a short-lived evolutionary phase characterized by considerably enhanced mass loss due to the occasional ejection of very dense envelopes.

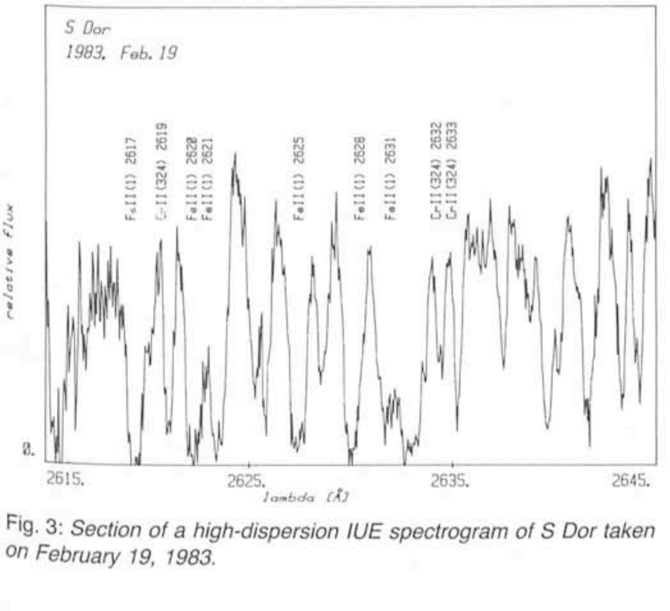

Fig. 3: *Section of a high-dispersion IUE spectrogram of S Dor taken on February 19, 1983.*

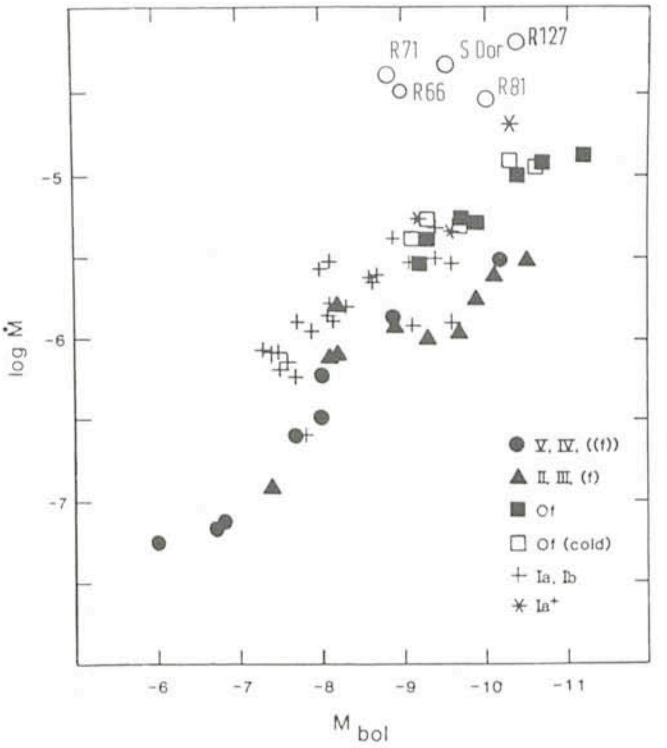

Fig. 4: *Location of the S Dor-type variables and related emission-line stars of the LMC in the diagram of Lamers (1981). Note the high mass loss rates of these objects compared with normal luminous supergiants.*

The New S Dor Variable R127 Intermediate Between Of and WN

It was conjectured earlier that the S Dor variables represent an important additional evolutionary phase in a scenario suggested first by P. Conti (1976). According to this scenario the very massive stars ($M > 50\ M_{\odot}$) evolve via Of to WN stars. A major difficulty of this scenario was that the observed mass-loss rates in the O- and Of phase appear to be not high enough to remove the hydrogen rich layers and expose the nuclear processed matter characterizing WN stars. Since the S Dor variables are losing much matter during their outbursts they may represent an important link between Of and WN stars. If this were true one would expect to find unstable Of stars with S Dor-type outbursts.

Therefore we included Of stars in a long-term monitoring programme searching for new S Dor variables in the LMC. Observing at La Silla on January 9, 1982, one of us (O.S.) found the extreme Of star R127 (= HDE 269858) 0.75 mag brighter in V than the value given by Mendoza in 1970. One week later the coudé spectrogram shown in fig. 5 was secured with the 1.5 m spectrographic telescope at La Silla. From these observations we suspected R127 to be a new S Dor-type variable. Therefore we decided to include R127 in the long-term photometric monitoring programme at La Silla, organized by Christiaan Sterken from Brussels (see his contribution in this issue of the *Messenger*). Within this programme we began to observe R127 on October 7, 1982 and found it to be as much as 1.3 mag brighter than Mendoza's V value. The observations obtained within this programme are shown in fig. 6. No doubt R127 has undergone an outburst. Both the light curve and the spectral appearance prove that a new S Dor variable has been discovered at La Silla. Needless to say that we now became eager to have this star observed with various kinds of instruments. R127 was subsequently observed by Italian colleagues

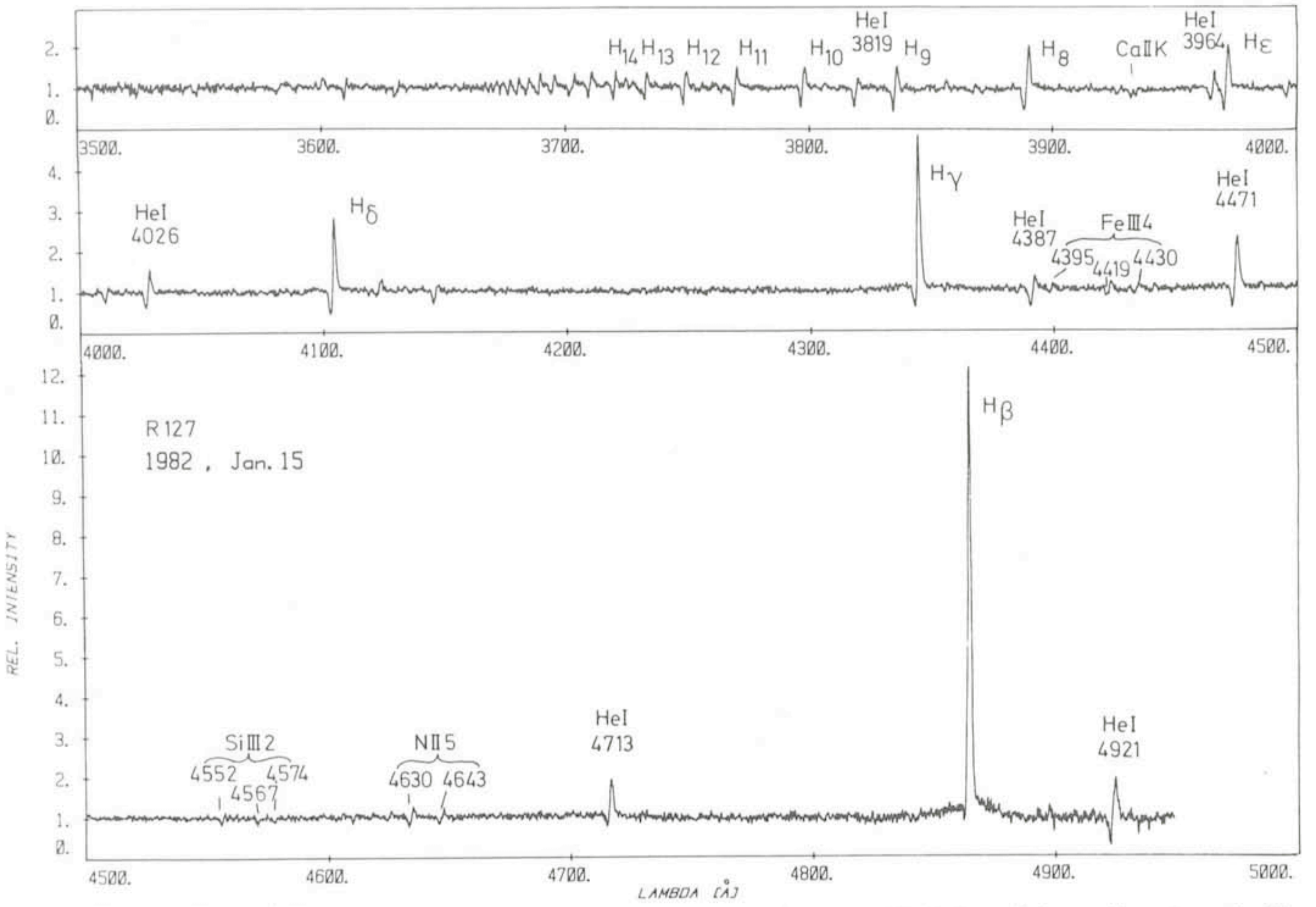

Fig. 5: *High-dispersion (20 Å mm^{-1}) spectrum of the newly discovered S Dor variable R 127 in the LMC (taken with the coudé spectrograph of the ESO 1.5 m telescope). Nearly all lines identified in the figure show pronounced P Cygni-type profiles.*

with the IDS attached to the 1.5 m telescope and with the infrared photometer (JHKLM) at the 1 m telescope. Further we spent 3 complete shifts with the IUE to observe R127 several times in the high and low resolution mode of both wavelength ranges 1200–1900 and 2000–3000 Å).

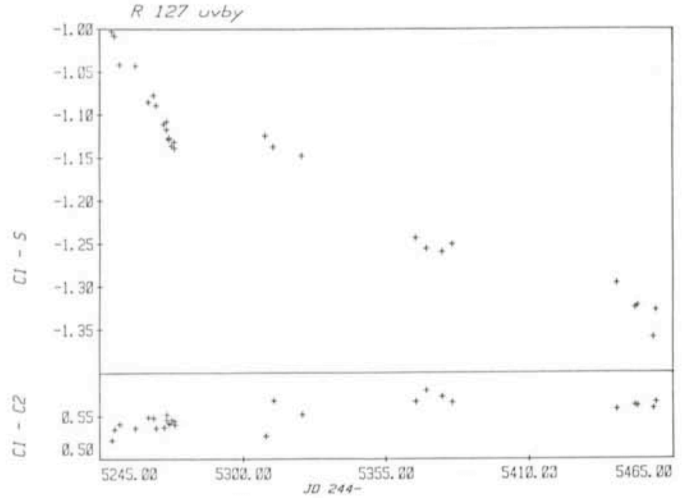

Fig. 6: *Strömgren y-magnitudes of R127 obtained within the photometric long-term monitoring programme, organized by C. Sterken, Brussels. The Bochum 60 cm telescope at La Silla has been used by various observers during this campaign from October 1982 to May 1983. A completely differential method is applied. Two nearby comparison stars (HD 37722, V = 8.84 and HD 37584, V = 8.30) were used. C_1-C_2 below the light curve indicates the photometric accuracy.*

Particularly interesting results were obtained with the IUE in the long wavelength range. Crowded lines of singly ionized metals were conspicuous in the spectrum of this Of star (!). The lines were split into three subcomponents as shown in fig. 7, indicating a very complex shell phenomenon.

We note that R127 is a particularly interesting member of the menagerie of S Dor variables. Its pre-outburst spectrum was classified by Walborn (1977) as Olafpe extr. It is the hottest S

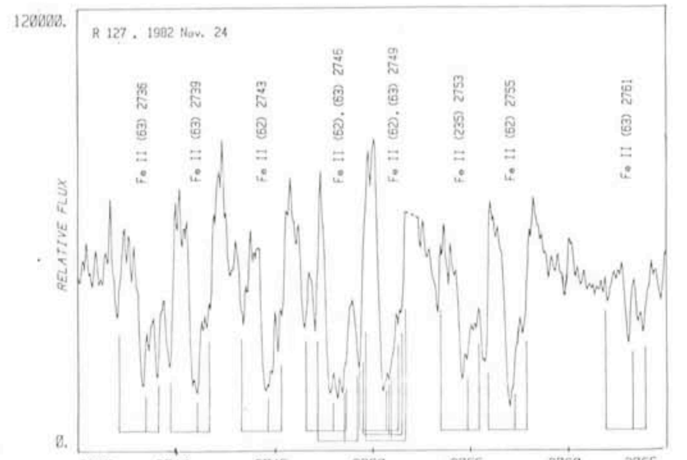

Fig. 7: *Section of high dispersion IUE spectrogram of R127. Note the triple substructure of the strong Fe II absorption lines. A very complicated shell structure is indicated by this.*

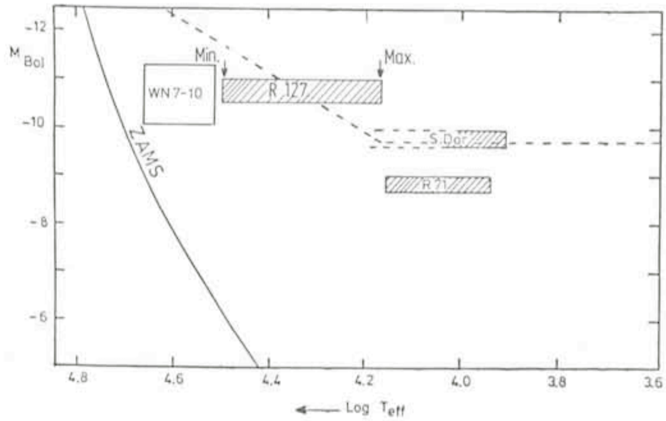

Fig. 8: *Location of the newly discovered S Dor variable R127 in the Hertzsprung-Russell diagram in comparison with the other two established S Dor variables of the LMC. Also included in the figure is the upper envelope of known stellar absolute bolometric magnitudes as derived by Humphreys and Davidson (1979). The approximate position of the late WN-type stars is also given.*

Dor variable detected and intensively studied so far. It is also one of the most luminous stars of its class with $M_{bol} \approx -11$ both during minimum and maximum (in contrast to the variations in the visual by 1.3 mag). Like for the other S Dor variables we explain this particular finding by the very high mass loss ($\dot{M} = 6 \cdot 10^{-5} M_{\odot} yr^{-1}$) during outburst. The variations in the visual are caused by bolometric flux redistribution in the envelope whilst the bolometric luminosity remains practically constant.

The location of R127 in the Hertzsprung-Russell diagram together with the other two known S Dor variables of the LMC are shown in fig. 8.

We note that Walborn classified R127 as an Of or alternatively as a late WN-type star. This indicates that the star is a late Of star evolving right now towards a WN star. Since we have detected an S Dor-type outburst of this star we conclude that this transition is not a smooth one but is instead accompanied by the occasional ejection of dense envelopes.

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Observations of Comet IRAS-Araki-Alcock (1983d) at La Silla

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As mentioned already in the last issue of the *Messenger*, a very exciting comet crossed the Earth's neighbourhood a few months ago. First discovered by the infrared satellite IRAS, then by two amateurs, Araki (Japan) and Alcock (UK), this comet approached the Earth with a minimum distance of 0.03 AU on May 12, 1983. The previous record of such a minimum distance was in 1770 with Comet Lexell.

This event provided a unique opportunity for studying a comet at very high spatial resolution. This is of major interest

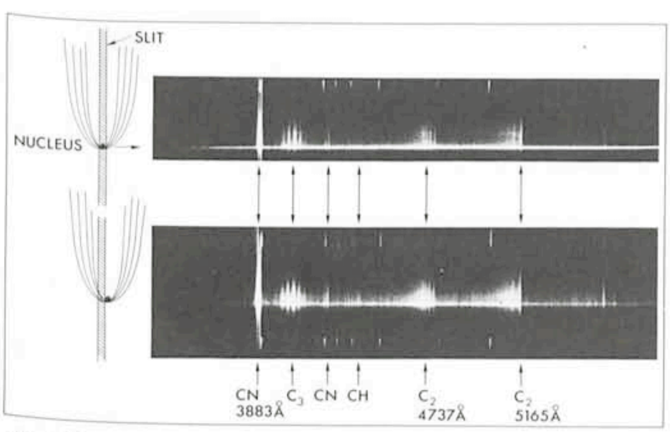

Fig. 1: *Image-tube spectra of Comet IRAS-Araki-Alcock obtained with the 1.5 m ESO telescope on May 13, 1983 at UT 00:20. The upper spectrum includes the nucleus (exposure time 2 minutes), while the lower spectrum has been obtained with the slit of the spectrograph out of the nucleus.*

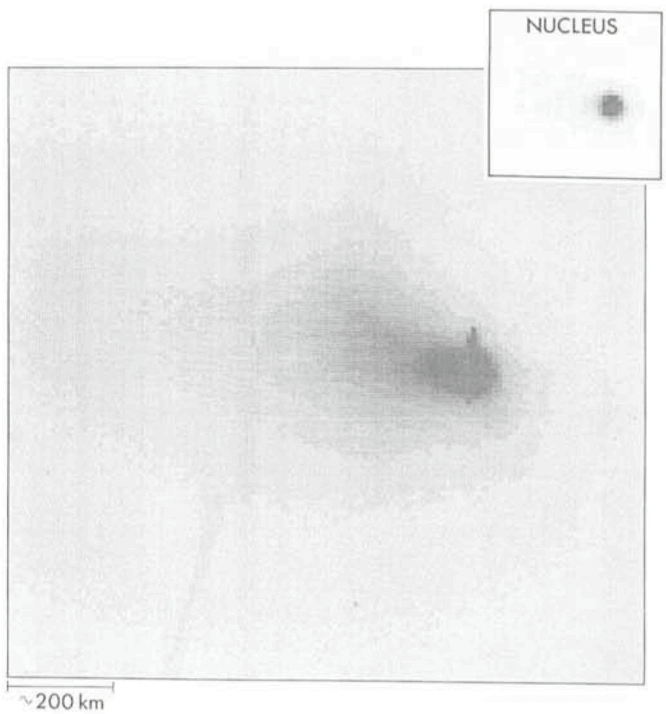

Fig. 2: *CCD images of the comet obtained in the Z filter (10000 Å) at the 1.5 m Danish telescope. In the 5 min. exposure image the nucleus is saturated. The insert image of the nucleus has been obtained with an exposure time of 1 min.*