The assumed absence of cosmological evolution thus appears to be compatible with present data even if it is clear that the statistical significance of our results is severely limited by the smallness of the samples.

Conclusion

The comparison between high and low excitation lines in the same absorption systems has strengthened our previous suggestion of the existence of a well-defined class of "low excitation absorbers". In these systems C IV and Mg II (or Fe II) lines are very strong with W_r (C IV λ 1548 or Mg II λ 2796) > 1 Å.

In our Galaxy, high latitude gas has been observed by IUE in front of Magellanic Cloud stars (Savage and de Boer, 1981). It shows an excitation degree very similar to that of the low excitation systems, although the components observed in our Galaxy are generally much weaker. Thus, it seems reasonable to think that these low excitation systems are associated with thick galactic disks. Their physical state (excitation degree, ...) would then be determined mainly by the local starlight radiation field. On the other hand, weaker C IV systems of higher excitation could be related to extended haloes, a phase which would be more sensitive to the external UV radiation field (integrated emission of the QSOs) and therefore more easily subject to cosmological evolution effects.

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Nova Muscae 1983: Coordinated Observations from X-rays to the Infrared Regime

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During recent years, coordinated observations in different wavelength regions with different instruments have turned out to be a very efficient means of studying variable objects. However, scheduling of such observations is a tricky problem, and one has to plan them well in advance. Difficulties increase, if facilities of several ground-based observatories and astronomical satellites have to be used. But what, if one wants to study a nova outburst? Nova outbursts are absolutely unpredictable and so rare that one does not have any meaningful chance to observe a nova during a normal observing run. There is only one solution for this problem: As soon as a nova outburst is announced, one has to organize an ad-hoc observing campaign. But for that one has to have luck. And that we had.

Let us now explain how we came by lucky circumstances to initiate an ad-hoc observing campaign on Nova Muscae 1983. Two of us (K.B. and J.K.) were on La Silla to carry out simultaneous IR and Walraven photometry of cataclysmic variables. A particular purpose of our programme was to observe dwarf novae in outburst. Since dwarf novae are numerous enough and the quasi period of their outburst short enough, one has statistically a very good chance to observe several of them in outburst during a seven-night run. For this purpose we had a collaboration with F. Bateson, the head of the amateur astronomers of the Royal Astronomical Society of New Zealand (RASNZ). He was to inform us via telex about dwarf nova outbursts detected by his amateurs. In fact, his first telex contained very valuable information; not on a dwarf nova outburst but rather a nova outburst, Nova Muscae 1983. This information from New Zealand reached us via a small detour: Nova Muscae had been discovered more than two days ago (January 18) by W. Liller in the Chilean town Viña del Mar which is about 500 km away from us in La Silla. W. Liller had sent the news of the outburst to the IAU bureau in Cambridge, Mass. From there it was transferred to New Zealand and then to us. The information had to travel 35,000 km, almost once around the earth, to reach us.

We immediately started preparations to observe the nova. At dinner we could persuade spectroscopists to take a spectrum of Nova Muscae. Problems arose due to the brightness of the object which could have damaged the detectors. The

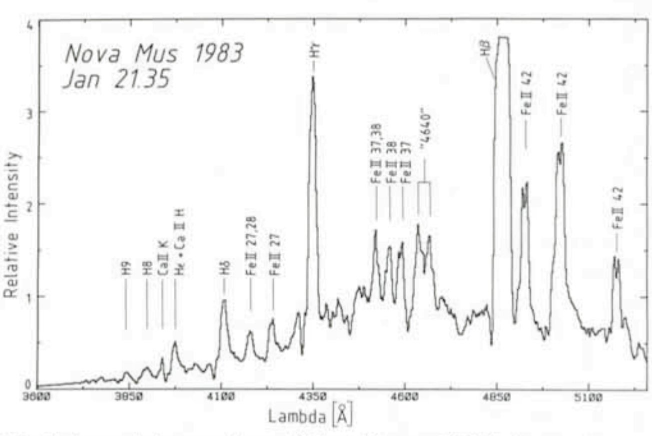


Fig. 1: *Image tube spectrum of Nova Muscae 1983 taken on January 21. The strong emission lines are heavily saturated. From Krautter et al. (1984).*

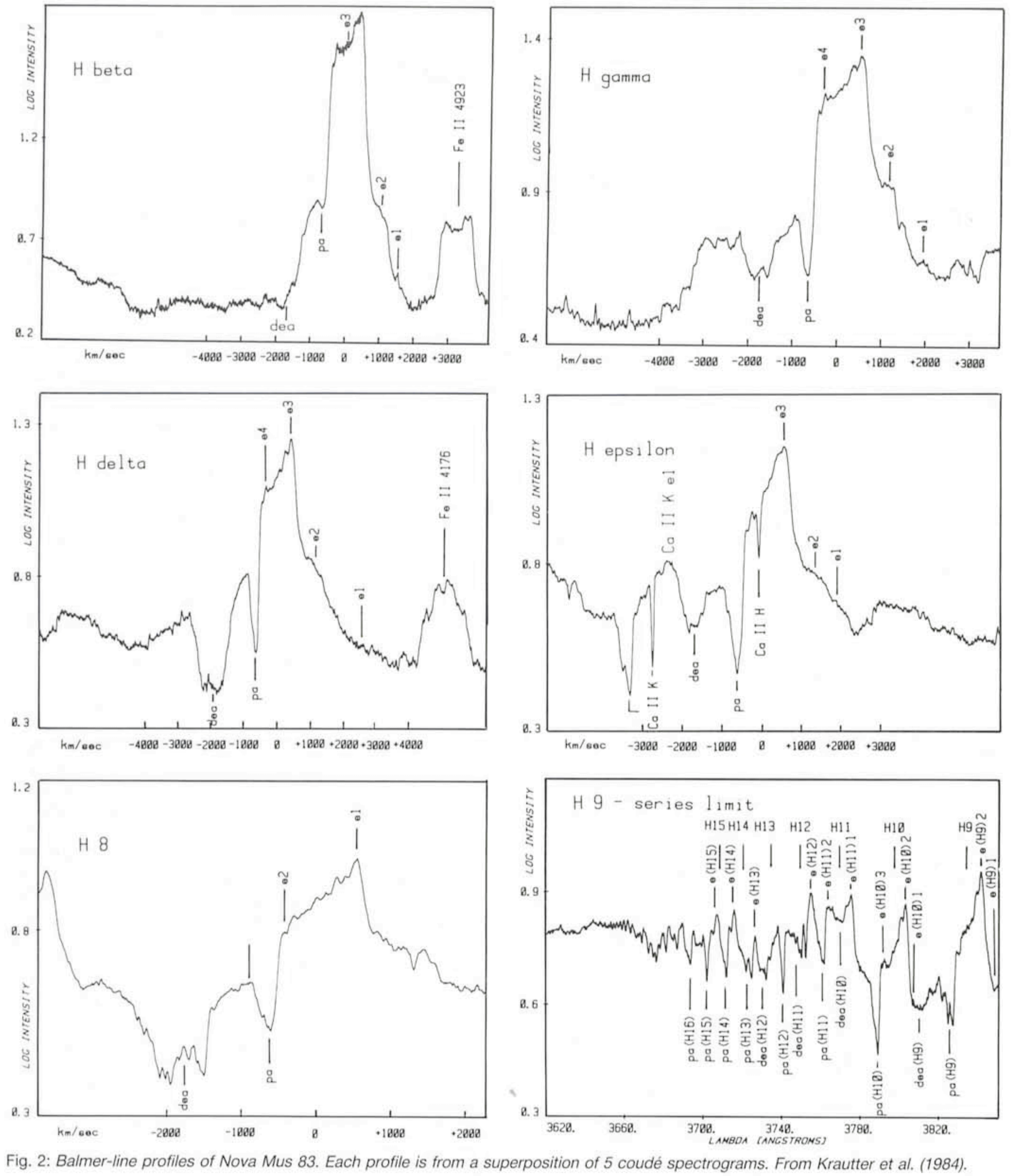


Fig. 2: *Balmer-line profiles of Nova Mus 83. Each profile is from a superposition of 5 coudé spectrograms. From Krautter et al. (1984).*

3.6 m observer solved the problem in a very simple way: he defocussed the telescope! This was the beginning of an extensive observing campaign of Nova Muscae, to which, eventually, some 25 astronomers, 8 telescopes on La Silla, and two satellites, IUE and EXOSAT, contributed. The main goal of this article is to show how the results from different spectral regions and different instruments interacted and complemented each other, and how we could, on the basis of these results, establish the fundamental parameters of Nova Muscae.

We started our spectroscopic observations of Nova Mus on January 21, 3 days after discovery, with 3 telescopes. Fig. 1 shows the first spectrum taken with the EMI image tube attached to the Boller and Chivens spectrograph at the 1.5 m telescope. The spectrum is dominated by strong emission lines of hydrogen and singly ionized metals which show two emission components at $v \approx -400$ km s^{-1} and $+500$ km s^{-1}. The Balmer lines show pronounced P Cygni profiles. More details can be seen in Fig. 2 which shows the Balmer line profiles on a superposition of 5 high-resolution coudé spectra

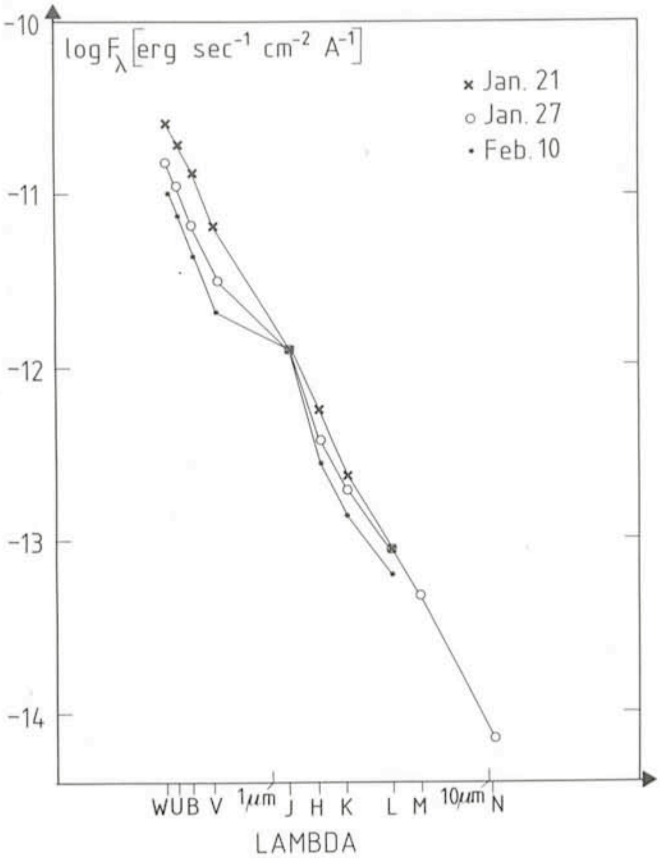


Fig. 3: *Flux distribution of Nova Mus 83 at different epochs. For dereddening E_{B-V} = 0.45 has been used. From Krautter et al. (1984).*

taken between January 25 and 29. No significant spectral changes took place between the first image tube spectrum and the last coudé spectrum. Two absorption systems are present: The principal absorption (v_{pa} = −588 km s^{-1}) and the so-called diffuse enhanced absorption system (v_{dea} = −1753 km s^{-1}). These velocities are typical for fast novae. The speed class of a nova (fast or slow nova) is defined by the lifetime t_3 which is the time it takes for the nova to decline from visual maximum by 3 magnitudes. If t_3 is less than 100 days a nova is called a fast nova. The knowledge of t_3 is important since a well defined relation between this parameter and the absolute magnitude exists.

But back to the spectra. When we did our first observations on January 21, Nova Mus had already undergone some evolution since its maximum brightness. The diffuse enhanced spectrum is characteristic for an advanced stage in a nova's life. Our next spectra taken on February 21 showed Nova Mus to be in the next phase of a nova's evolution, the so-called "Orion" stage. This stage is characterized by a new absorption system with the highest velocity (v = −1980 km s^{-1}) and the appearance of typical emission lines like He II, N II, etc. The 4640 Å C II–N III feature reaches maximum strength.

Our photometric observations (visual + IR) enabled us to determine the spectral energy distribution (SED) which is shown in Fig. 3 for 3 different epochs. For dereddening we used E_{B-V} = 0.45 which we derived from the 2200 Å feature in the UV spectrograms taken with the IUE. Generally the flux increases towards shorter wavelengths obeying a power law $F_\lambda \propto \lambda^{-\alpha}$ with $2 \leq \alpha \leq 2.3$. The overall intensity dropped by about a factor of 1.5 from January 21 to February 10. This spectral energy distribution is characteristic of free-free emission of an optically thin gas clearly showing that our first observations were after maximum brightness. General wisdom tells us that the free-free phase is already the second phase in the evolution of a nova's SED which is at maximum that of blackbody radiation from an optically thick pseudophotosphere. The onset time ot the ff radiation depends on the speed class. For Nova Cyg 75, the fastest nova ever observed, the ff phase onset was 4.2 days after maximum. For other fast novae the ff phase began later, for instance for Nova Cyg 78, 8 days after maximum. It is therefore highly improbable that Nova Muscae was at maximum brightness at its detection on January 18, 3 days before our first observations.

But how does one get the visual maximum brightness which is crucial for determining the absolute magnitude via the luminosity lifetime relation? Fortunately, there are relations between the appearance and disappearance of spectral features and the change in the magnitude compared to the maximum brightness. Using these relations, we derived a most probable $V_{max} \approx 7.0$ mag.

Next we investigated the visual light curve in order to determine t_3. Fig. 4 shows the visual light curve till January 1, 1985. Since our photoelectric measurements cover 40 days only, this light curve has been prepared by using exclusively the visual data published by the amateur astronomers of the RASNZ. The extrapolation of the light curve back to V = 7.0 suggests that maximum brightness was reached around January 14–15, 3–4 days before the discovery. This enabled us to determine t_3 as 40 days which is turn gave M_V = −7.75 and a distance D = 4.8 ± 1 kpc. With this distance we could derive lower limits for the luminosity which are of the order of one Eddington luminosity for a 1 $M_\odot$ white dwarf.

What did we learn from the spectroscopic observations in the infrared and ultraviolet spectral regimes? The IR results are already described in a *Messenger* article by E. Oliva and A. Moorwood (1984, *The Messenger* **33**, 30). Additionally, we inferred from the IR spectra that the lower limit of the helium abundance is slightly above solar abundance. Fig. 5 shows a low resolution IUE spectrum of Nova Muscae taken on March 4, 1983. We have already mentioned that we could determine the interstellar extinction from the 2200 Å feature. The UV spectrum shows a wealth of emission lines. Dominant are those from neutral or low ionized atoms. Lines from highly ionized and/or excited levels are present too, but are generally weaker than the other lines. Very conspicuous are intercombination lines like N III], N IV], C III], Si III], and O III]. From the strength of the CNO lines we were able to derive crude abundances of these elements relative to each other. The results are N/C = 20 and N/O = 2.4 showing that nitrogen is strongly overabundant with respect to carbon and oxygen. This high nitrogen abundance is entirely consistent with the thermonuclear runaway models of nova outbursts with hydrogen being burnt via the CNO cycle. This conclusion is also supported by the luminosity of Nova Mus of about one L_{Edd}.

From March 1983 to March 1984 we did not continue our observations of Nova Muscae. However, other observations revealed some peculiarities which we summarize below.

– From April 1983 to February 1984 the visual magnitude was nearly constant (apart from the short flare around September 1). The decline rate is very low. This is very unusual for a fast nova.

– IUE observations carried out on June 13 showed a second outburst in the UV range (A. Cassatella, private communication). No indication for this outburst is found in the visual light curve nor in spectra taken in the visual spectral range on June 14 and 15 (W. Liller and M.T. Ruiz, private communication).

In spring 1984 we continued our observations of Nova Muscae which had now entered its last phase of evolution, the nebular stage. Again spectroscopic and photometric observations on La Silla and with IUE were carried out. For the time

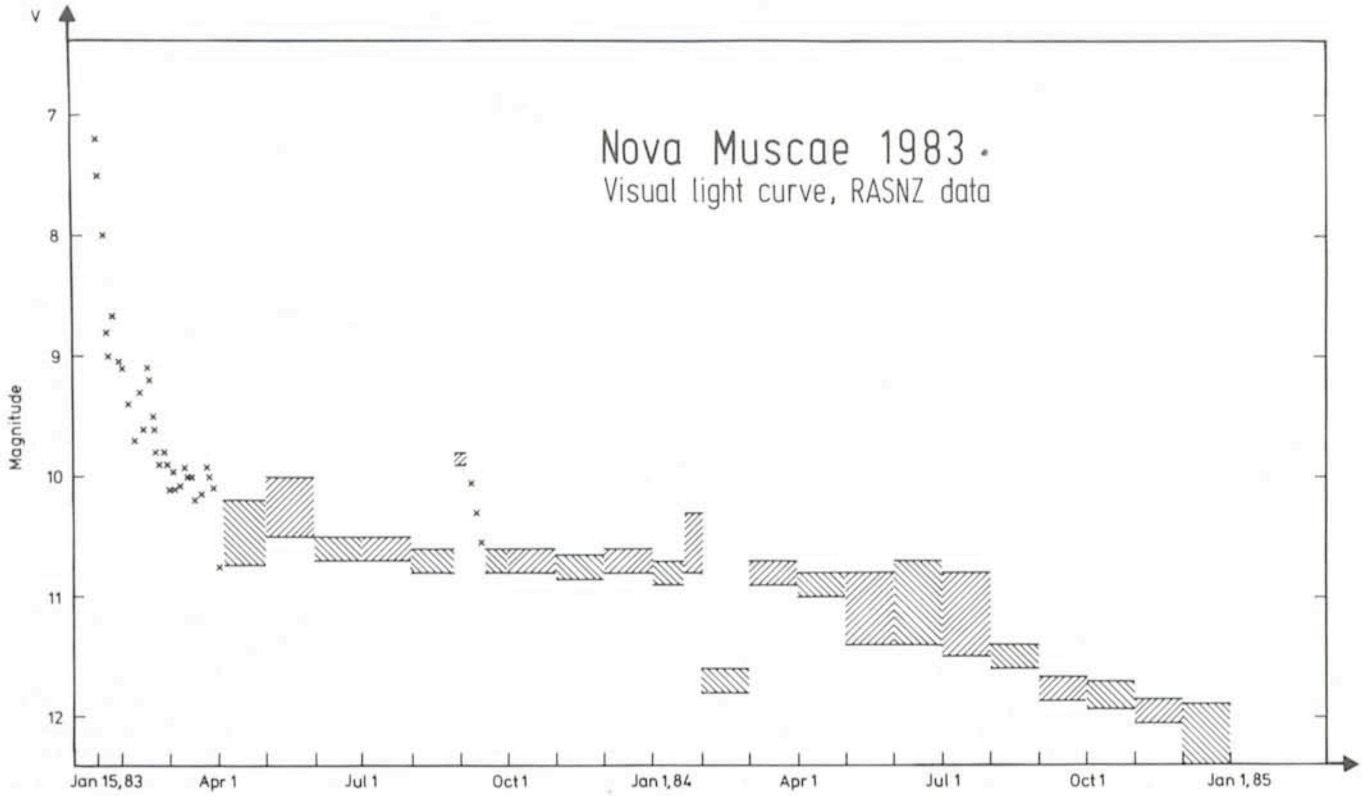


Fig. 4: *Visual light curve of Nova Mus 83 from January 18, 1983 to January 1, 1985. Only visual data published by the variable star section of the RASNZ have been used. Crosses denote individual observations. The shadowed areas show the monthly bandwidths of the visual measurements as published in the information bulletins of the RASNZ.*

being we can only present preliminary results of these observations. Figs. 6 and 7 show the same low-resolution spectrum taken with the IDS at the ESO 1.5 m telescope on two different scales in order to account for the large differences in emission-line intensities. The spectrum is dominated by strong nebular emission lines. Many highly excited lines are present, the strongest being [FeVII] λ 6087. A particularly interesting result is that we could also identify the coronal lines [FeX] λ 6074 and [FeXIV] λ 5303. Coronal line emission has been reported for several other novae, but to our knowledge [FeXIV] has been found only in one other nova yet, DQ Her.

By now, we had collected observations of the nova from 1200 Å to 10 μm. But what about X-ray emission? Why not look with EXOSAT for the X-ray emission? Among previous novae a few had been observed with earlier X-ray satellites during outburst or decline from outburst. But none of them was detected in X-rays. One reason for these negative results may be that the X-ray observations were carried out in the very early outburst phases soon after maximum brightness. In the beginning the envelope has a high density and the soft X-ray radiation is absorbed. In the case of Nova Muscae more than one year had passed since its maximum brightness. An estimate showed that the envelope should have been expanded enough to be transparent to soft X-rays. This encouraged us to propose Nova Muscae as target of opportunity for EXOSAT observations. The case was convincing enough for Dr. A. Peacock, the project scientist of EXOSAT, to declare Nova Mus as target of opportunity, and allocate observing time. On our first EXOSAT observation on April 20, 1984, we detected Nova Mus in the soft X-ray range (.04–2 keV) in two broadband filters: Lexan and Al-Parlene. The count rates were 3.4 ± 1.2 10^{-3} cs^{-1} (Lexan) and 3.7 ± 1.2 10^{-3} (Al-Parlene). Both observations taken together give a 4.5 σ statistical significance. This observation constitutes the first detection of X-rays from classical novae during outburst, including the decline stage.

Subsequently we were granted further observing time on EXOSAT, and we carried out two more observations on July 15, and December 22, both times with the Lexan filter only. The count rates were 3.0 ± 0.6 10^{-3} and 3.4 ± 0.9 10^{-3} c s^{-1} respectively. The X-ray flux has, within the error limits, been constant during the last 9 months. On the other hand, the visual brightness has significantly declined, as Fig. 4 shows.

Unfortunately, the low-energy data did not allow to determine the spectral characteristics with any meaningful accuracy because of the errors in the counting rates and the large overlapping bandwidths of the two filters. In order to gain physical insight into the nature of the X-ray emission we had to compare our measurements to models of nova outbursts. There are in principle two possible regions that may be

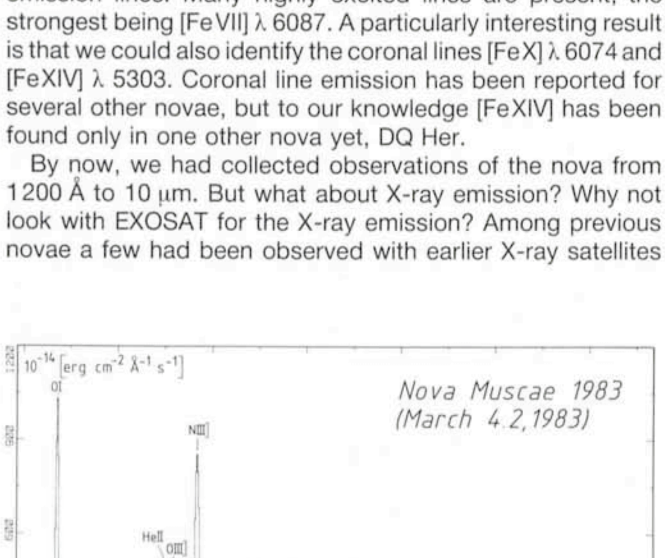
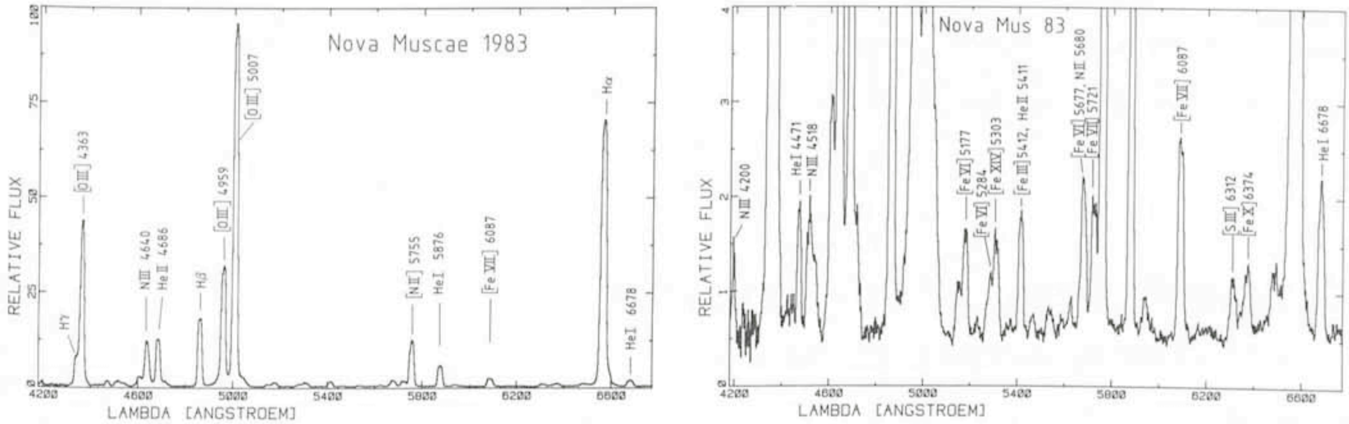


Fig. 5: *Combined SWP and LWR UV spectrograms taken with IUE on March 4, 1983. The more significant emission lines are indicated. From Krautter et al. (1984).*



Figs. 6 + 7: *IDS spectrum of Nova Mus 83 taken on March 29, 1984 shown on two different ordinate scales. The most prominent emission lines are indicated.*

associated with the X-ray emission: the expanding shell or the white dwarf remnant. For the emission associated with the expanding shell, Brecher et al. (*Astrophysical Journal* **213,** 1977) have suggested a model in which it is predicted that as the ejected nova shell moves through circumstellar gas it will heat it to characteristic temperatures around 1 keV and produce thermal bremsstrahlung in the X-ray region. Our measurements are consistent with this type of emission provided that the temperature is less than 3 keV and the total unabsorbed low energy X-ray luminosity is about 10^{35} erg s^{-1}. The model predicts that the X-ray flux should decay as t^{-1}.

The alternative for the origin of the detected X-ray emission is the white dwarf itself. In hydrodynamic models of nova outbursts it was found that after several per cent of the hydrogen envelope is ejected during the hydrodynamic phase of the outburst, the velocity in the deeper zones drops quickly and hydrostatic equilibrium is established. The further evolution of the remnant is on nuclear burning time scale and thus may last for many years. For more details of these models we refer to e.g. Truran (in: *Nuclear Astrophysics,* ed. Barnes, Clayton, Schramm, Cambridge 1982).

In order to compare the measured soft X-ray flux with the parameters of the hydrostatic remnant, we have drawn in Fig. 8 the lines of constant luminosity that will give the measured X-ray counting rate under different values of kT and N_H for a blackbody type emission spectrum at 4.8 kpc distance. N_H is the column density of the interstellar hydrogen which causes the absorption of the soft X-rays. The range of the acceptable N_H was determined from $E_{B-V} = 0.45 \pm 0.15$ we derived from the UV spectra. Also drawn in Fig. 1 are lines of constant radius objects that will give the observed soft X-ray counting rates under the assumption that they radiate like a blackbody at temperature T and subsequently the radiation suffers an absorption corresponding to the value of N_H on the figure. It is immediately apparent from the figure that in the acceptable range of N_H values an object radiating at L_{Edd} (10^{38} erg s^{-1}) has to have a temperature around 0.025 keV (280,000 K) and its radius has to be less than 5×10^9 cm. Conversely, if we assume that the object radiating the X-rays is the white dwarf itself, then the implied luminosity would be about 10^{37} erg s^{-1} with a corresponding temperature around 0.03 keV (350,000 K).

At present we cannot decide between either of these models. A crucial test would be the determination of the spectral characteristics. At present, our time base is too short and/or the accuracy of the data not sufficient enough, to really exclude a t^{-1} dependence. A possible verification of the white dwarf origin would be the first direct observational proof of the nuclear shell burning predicted by the thermonuclear runaway models of nova outbursts.

This, at present, concludes the story of Nova Muscae 1983 which started in La Silla two years ago. We hope we have been able to stress the importance of observations in different spectral regions for variable objects like novae. Part of the results described here and additional information can be found in Krautter et al. (1984, *Astronomy and Astrophysics* **137,** 307) and Ögelman, Beuermann, and Krautter (1984, *Astrophysical Journal* Letters **287,** L31). We want to thank all colleagues who kindly contributed to the observations and spent part of their observing time on Nova Muscae: L. Bianchi, J. de Bruyn, E. Deul, H. Drechsel, R. Häfner, A. Heske, G. Klare,

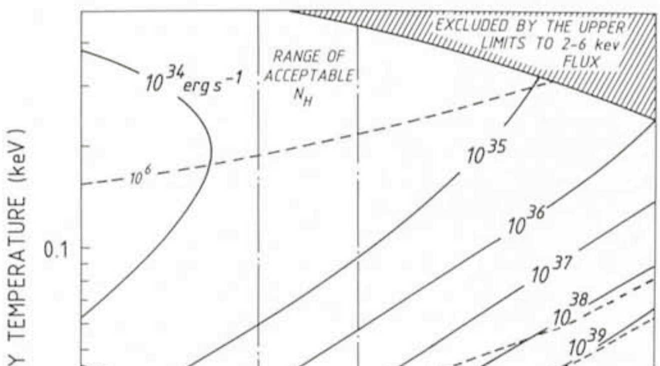


Fig. 8: *Summary of the observed X-ray flux from Nova Muscae 1983 for various N_H and kT combinations. The source spectrum was assumed to be that due to a blackbody at temperature T and at a distance of 4.8 kpc. The contours of constant source luminosity (in erg s^{-1}) that gives the observed soft X-ray counting rates are shown. Also shown in the figure are the radii (in cm) contours of objects that will radiate the required luminosity under the assumption that they are radiating as a blackbody at temperature T (dashed lines). From Ögelman, Beuermann and Krautter (1984).*

L. Kohoutek, C. Leitherer, J. Manfroid, A. Moorwood, Th. Neckel, E. Oliva, M. Pakull, W. Schlosser, R. Schulte-Ladbeck, O. Stahl, B. Stenholm, J. van Paradijs, N. Vogt, W. Wargau, B. Wolf, and F. J. Zickgraf. We also thank A. Peacock for granting observing time on EXOSAT, and, last not least, we cordially acknowledge the very valuable work F. Bateson and his amateur astronomers of the RASNZ did for Nova Muscae 1983.

On the Problem of the Luminous Emission Line Stars

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Introduction

Emission-line spectra are frequently observed among stars of high intrinsic luminosity. They provide evidence for the presence of extended stellar atmospheres, probably resulting from intense mass outflows. However, the physical relation between the strength of the emission lines and other stellar parameters, such as luminosity, gravitiy, temperature, rate of mass loss, rotation, binarity, etc. is far from clear. This situation is probably the result of the poor knowledge that we have of their basic physical parameters, and of the mechanisms of line formation in extended atmospheres. One major problem for galactic objects is the determination of their distance and interstellar reddening because of their position near the galactic plane. Many objects are also affected by a considerable amount of circumstellar extinction, and these problems make the determination of their intrinsic (bolometric) luminosity even more difficult. Another problem is the correct estimate of their temperature (or radius). In fact, as discussed for instance by de Jager (1980), these superluminous stars generally display a very tenuous stellar atmosphere so that both the brightness temperature and the radius at optical depth equal to unity largely vary with wavelength. The result is that for the most interesting objects their position in the Herzsprung-Russell diagram is quite uncertain, and it is therefore difficult to discuss them in the framework of the current evolutionary theories.

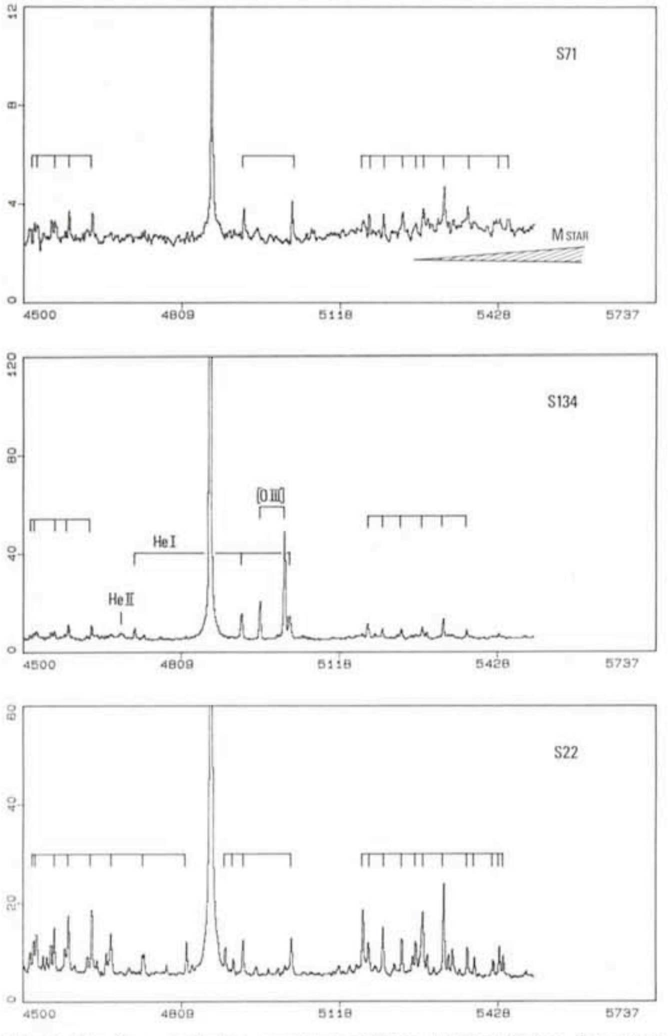

Fig. 1: *The low-resolution spectrum of three LMC emission-line stars: (a) S71, a VV Cep star characterized by low excitation emission lines and an M-type spectrum in the red. The FeII emission lines are marked. (b) S134 (HD 38489) with both low and high ionization emission lines. (c) S22 (HD 34664) with one of the richest Fe II emission spectra. Both S22 and S134 are known to have circumstellar dust shells (Bensammar et al. 1981, Stahl et al. 1984). Spectra taken by R. Gilmozzi on November 21–22, 1983 (ESO 1.5 m + IDS). Fluxes are in units of 10^{-14} erg cm^{-2} s^{-1} Å^{-1}.*

On the other hand, the interest in these stars has recently increased, as they may represent a phase, or different phases of the evolution of massive stars after having left the main sequence (see e. g. the Proceedings of the ESO 1981 Workshop on "The Most Massive Stars"). Because of their high intrinsic luminosity, they can be identified also in distant galaxies, and this has been improved by the wide use of the new astronomical techniques. Obviously, the presence of prominent emission lines makes their identification with wide-field cameras easier than for the more normal early-type supergiants.

The Magellanic Clouds may represent the best laboratory for the study of the behaviour of luminous emission-line stars, since their distance is well known and the interstellar extinction is in general low. In addition, the difference in metallicity and stellar content among the clouds makes them an ideal case to study chemical composition effects. For this reason many projects of systematic investigation of the emission-line stars in the MCs are now under way (e. g. Shore and Sanduleak 1984, Stahl et al. 1985, Gilmozzi et al. 1985), with the aim of determining the main physical characteristics of these objects. In the following we shall illustrate some results obtained from the analysis of the optical (ESO) and ultraviolet (IUE) spectra of galactic and MC superluminous stars.

Spectroscopic Observations

The luminous emission-line stars show a large variety of optical spectra, with different degrees of line excitation and intensity. Fig. 1 shows three examples of Magellanic Cloud stars with emission lines. In general the emission lines are more prominent and more numerous in the brighter objects, while the *photospheric* (not P Cygni) absorptions are weak or not observable at all. Besides hydrogen and helium, Fe II is the most frequently observed ion in the optical spectrum of