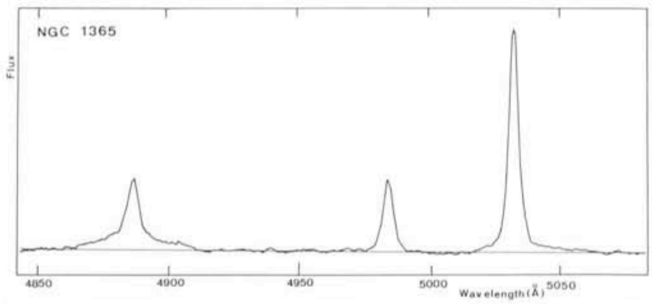

Fig. 1: *Spectrum of NGC 1365 obtained with the Boller and Chivens spectrograph and the IDS attached to the ESO 3.6 m telescope. The exposure time was 30 min, the entrance aperture 2 by 4 arcsec. A dispersion of 60 Å/mm was used, which gives a resolution of about 3.2 Å (FWHM). The emission lines shown here are* Hβ and [OIII] λλ 4959, 5007.

Most of the spiral Seyfert 1 galaxies have permitted Fe II lines in their spectra but the forbidden [Fe II] lines are usually not observed; if they are suppressed by collisional de-excitation, then Ne $\gtrsim 10^7$ cm^{-3} (Phillips 1978, *Ap. J. Suppl.* **38,** 187). However, both the forbidden and the permitted Fe II lines have been observed in the spectrum of the Seyfert 1 galaxy I Zw 1, which yields to a density Ne $\sim 10^7$ cm^{-3} (Oke and Lauer 1979, *Ap. J.,* **230,** 360).

In the course of a spectroscopic study of the line profile in emission-line galaxies, carried out with the ESO 3.6 m telescope on La Silla, we have found out that, in addition to a broad Hβ component, the spectrum of two Seyfert 1 galaxies (NGC 1365 and NGC 7469) show a broad component under the forbidden line [OIII] λ 5007 (Fig. 1). In both cases, the intensity of the broad N2 component is about half of that of the broad Hβ component. For the narrow components, we have I(N2)/I(Hβ) = 4 and 6 for NGC 1365 and NGC 7469 respectively. If we made the assumption that the excitation condition in both the low and high density regions are the same, then, in the broad line region, the N2 line is collisionally de-excited by a factor of 8 and 12 respectively.

According to the formula given by Seaton (1975, *M.N.,* **170,** 475), this implies a density of $(1-3) \times 10^6$ cm^{-3} for an electron temperature in the range Te = $(1-3) \times 10^4$ K. In NGC 7469, the [OIII] λ 4363 narrow line is rather strong, being about a tenth of the strength of the narrow component of the [OIII] λ 5007 line, indicating a rather high temperature in the low density region (Wampler 1971, *Ap. J.,* **164,** 1; Anderson 1970, *Ap. J.,* **162,** 743); if the temperature is the same in the high density region, the broad component of the λ 4363 line would be as strong as the λ 5007 line, as, at densities not exceeding 3×10^6 cm^{-3}, the auroral line is not significantly suppressed by collisions.

These observations have shown that the broad emission-line regions of Seyfert 1 galaxies may have densities as low as $\sim 10^6$ cm^{-3}, much smaller than previously thought.

We plan to try to detect the auroral line of [OIII] in these two galaxies and to observe more bright Seyfert 1 galaxies to find out if such low densities are common in the broad line regions.

Optical and Ultraviolet Spectroscopy of the Nuclei of Seyfert Galaxies

H. Schleicher and H. W. Yorke, Universitäts-Sternwarte, Göttingen

The launching of the International Ultraviolet Explorer (IUE) in 1978 has made the ultraviolet sky in the wavelength region from 1150 Å to 3200 Å accessible to detailed spectroscopic study. The IUE is a satellite in a geosynchronous orbit, equipped with a 45 cm telescope with two spectrographs. For a more detailed description of this satellite, the interested reader is referred to the article by A. Heck et al. (*Messenger* No. 15, Dec. 1978). Although the diameter of the IUE telescope is quite small—its size is more typical of an amateur telescope than of a scientific instrument—it has been used successfully even for extragalactic spectroscopy.

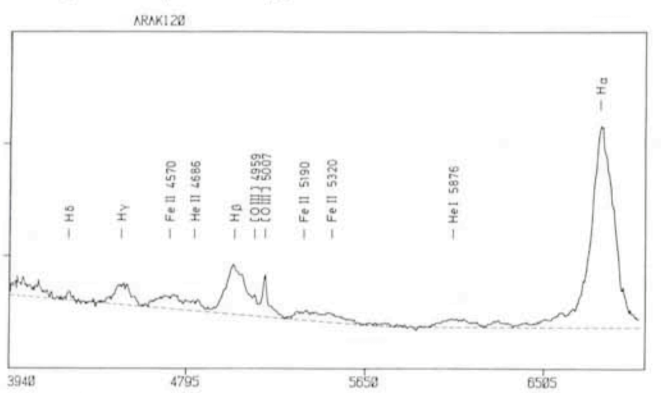

Fig. 1: *The optical spectrum of Akn 120, obtained with the IDS. The relative flux is plotted versus observed wavelength. No correction due to galactic extinction has been applied. The dashed line indicates the continuum.*

Seyfert Nuclei

The nuclei of Seyfert galaxies have become popular subjects for research, since it was realized that they resemble QSOs in several respects. Seyfert nuclei have smaller redshifts than QSOs; they are much less luminous and are embedded in a clearly visible galactic disk. The optical spectrum of a Seyfert nucleus is dominated by very broad emission lines of the Balmer sequence and by the relatively narrow forbidden lines of [O III] (in this article we will restrict ourselves to the case of Seyfert 1). Several other broad, but weaker, emission lines seen in Seyferts originate from He I and Fe II. Fig. 1 shows the optical spectrum of Akn 120, which one of us (H. S.) obtained with the IDS at the ESO 3.6 m telescope. Note the asymmetric, bumpy structure of the Balmer lines. The shapes of the permitted lines can be explained by a model in which the gas is confined in clouds or filaments surrounding a central compact source of continuum radiation. These filaments move relative to each other with high velocities. A bump in the Hβ profile of Akn 120, e.g. 80 Å shortward of line centre, would be produced by filaments which move towards us (relative to the mean velocity of all filaments) with a velocity component of 4800 km/s. Obviously the narrow forbidden lines originate in a different region of the nucleus with much smaller internal velocities ($\lesssim$ 600 km/s). Forbidden lines occur only if the electron density is less than $\sim 10^7$ cm^{-3}. The absence of broad wings in the [O III]-lines therefore indicates that the electron density exceeds 10^7 cm^{-3} in the "broad line" filaments.

Unfortunately, not much more information on the physical conditions in the broad line region can be extracted from optical spectra alone. The hydrogen and helium lines are produced mainly by recombination, and their intensities therefore depend only weakly on temperature and densities. Saturation effects complicate their interpretation. The Fe II ion has a rather complex structure and the values of its atomic parameters are very uncertain.

The situation can be improved by including the ultraviolet spectra in the analysis. Here most of the conspicuous lines are produced in transitions from levels 4 to 10 eV above the ground state. Because these lines are generally more sensitive to collisional processes than optical lines, their intensities provide stronger constraints for models of the broad line region.

Observations

In 1978 our group in Göttingen (K. J. Fricke, W. Kollatschny, H. Schleicher, H. W. Yorke) began a programme of observing active galaxies in the optical and UV spectral regions. We first compiled a list of 12 Seyfert galaxies with bright cores suitable for the IUE. This sample included a wide range of intrinsic luminosities and degrees of activity. In our original programme, however, we underestimated the amount of IUE exposure time necessary for a good spectrum, and overestimated the amount of IUE time which we thought would be alloted to us, both by a factor of at least two. The three Seyfert galaxies (NGC 1566, NGC 7603, Akn 120), which we in fact observed with the IUE, were chosen more by accident than by intention. Some objects had to be excluded at the time of observing, because they were too close to the sun, moon or earth. Other objects had already been observed by colleagues in the meantime. As a further constraint, we did not wish to use too much of our allotted IUE time positioning the satellite – under extreme conditions the IUE needs more than two hours to move across the sky over a wide angle.

The IUE observations were made in August and November 1979 in the IUE low spectral resolution mode. Optical observations with the ESO 3.6 m telescope were made in October of the same year. The time differences between UV and optical observations were 70 days and 20 days, a fact which is very important, considering the time variability of these sources. Using the IDS we scanned eight galaxies, including the three galaxies observed with IUE in the wavelength range $\lambda\lambda$ 3940–7200 with a dispersion of 171 Å/mm for a spectral resolution comparable to our UV spectra.

From the viewpoint of a visiting astronomer not intimately familiar with the sophisticated IDS and IUE systems, we were grateful that all technical handling of the apparatus was conducted by skilled observatory staff members. The activity of the visiting astronomers during the measurements is more or less restricted to identifying the objects, specifying the exposure time and occasionally complaining about the poor signal-to-noise ratio.

Results

In the following we will discuss some of the most important features of the spectrum of Akn 120, the strongest of the three sources observed in the UV. The optical and UV spectra are shown in Fig. 1, 2 and 3. The redshift of Akn 120, known to be z = 0.0325, can easily be seen in Fig. 3, by comparing the intrinsic Lyα emission line to the non-redshifted geocoronal Lyα line at λ 1216.

Before any further interpretation of these spectra can be made, one has to correct for selective absorption effects caused by dust along the line of sight.

Using 21 cm maps from Burstein and Heiles (1978), we estimated the amount of neutral hydrogen and thus the amount of dust in our own galaxy in the direction towards Akn 120. We derived a value of E(B–V) = 0.095, which implies a correction of a factor of about 2 for the flux near the Lyα line. The effect of dust within the source itself is much more difficult to estimate. Here, recombination line ratios are useful, because of their weak dependence on temperature and density. Recombination theory predicts a value for He II 1640/He II 4686 of about 7. We measured a line ratio of about 5. However, both lines are blended with other lines (mainly Fe II) and our observed line ratio is therefore uncertain by a factor of 2. We conclude that the amount of dust intrinsic to Akn 120 does not exceed E(B–V) = 0.15.

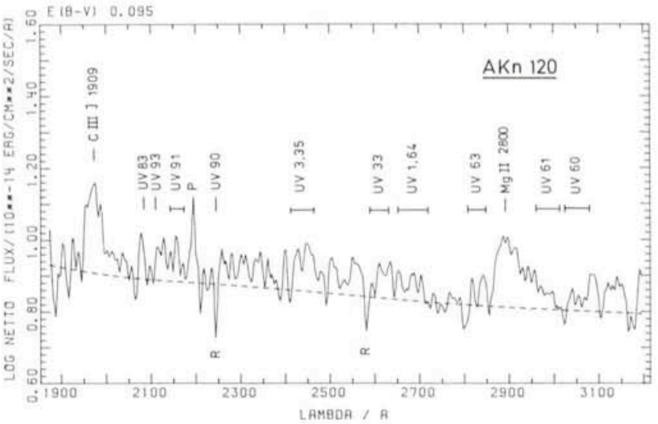

Fig. 2: *UV spectrum of Akn 120 obtained with the long wavelength camera of the IUE. The logarithm of absolute flux, corrected for galactic extinction, is plotted versus observed wavelength. Only multiplets of Fe II expected to be strong are indicated. P is a camera blemish, R denotes reseau marks.*

The spectrum of Akn 120 in the wavelength region $\lambda\lambda$ 2700–2800 (see Fig. 2) lacks conspicuous emission lines. However, there are a large number of broad but shallow Fe II lines which overlap and thus form a "pseudo-continuum". The energy emitted by the Fe II lines in the UV could in fact be as large as a factor of 5 greater than that emitted by the optical Fe II lines.

Correcting for galactic absorption only, we find an intensity ratio Lyα/Hβ of 10. For the past few years, the intensity ratio Lyα/Hβ has been under extensive discussion. Prior to the launching of IUE, measurements of high redshift QSOs in the optical (for Lyα) and the infrared (for Hβ) yielded values between 2 and 5, whereas standard recombination theory

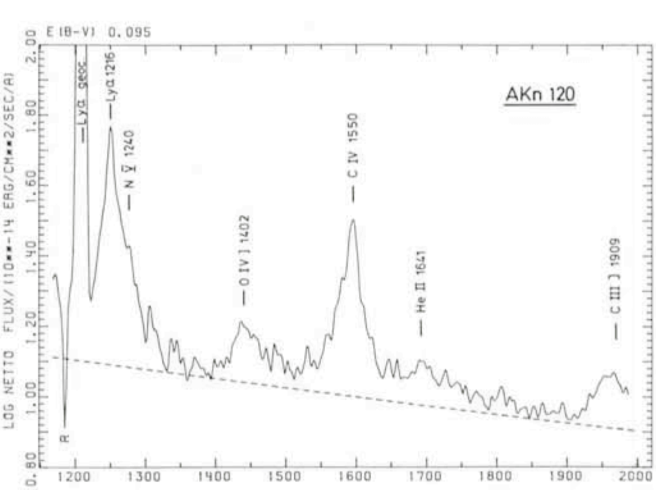

Fig. 3: *Same as Fig. 2 for the short wavelength camera of the IUE.*

predicts a value around 40. Even when saturation effects in the Balmer lines and collisional processes are taken into account, the expected line ratio is not changed very much. In order to explain this discrepancy, Ferland and Netzer (1979: *Astrophysical Journal,* **228,** 274) have included the effects of internal dust in their calculations and obtain a value $Ly\alpha/H\beta = 13$ for internal $E(B-V) = 0.15$. This model is marginally consistent with our results. If Akn 120 were to have no internal dust, however, there would still be a discrepancy of at least a factor of 3 between observation and theory.

Fortunately, the important line ratios Lyα/C IV 1550/He II 1640/C III] 1909 are not affected strongly by internal dust as long as $E(B-V) < 0.15$. We have compared our observed values with dust-free model calculations by Davidson and Netzer (1979: *Reviews of Modern Physics,* **51,** 715) and obtain

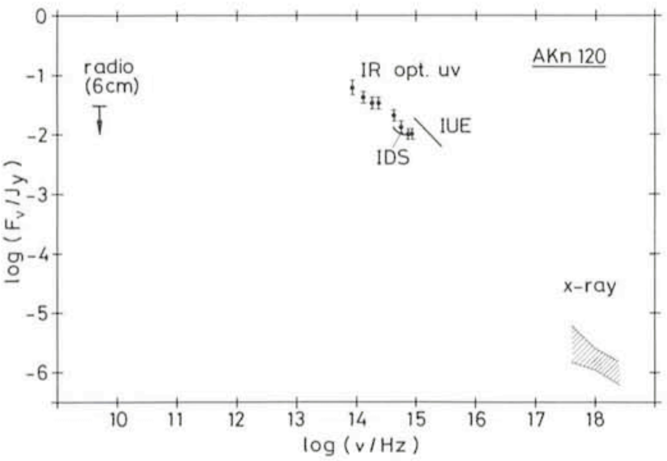

Fig. 4: *The overall spectrum of Akn 120, combining observations in various frequency ranges by several authors during 1968 to 1980. At 5 GHz (6 cm), only an upper limit of the flux is known.*

a reasonable fit for a certain value of the adjustable parameter U_1. U_1 is equal to the ratio of the density of incident ionizing photons to the electron density in the broad line filaments. Once a value for U_1 has been fixed, the temperature and ionization stratification within the filament is given. Due to the presence of the C III] 1909 line, the electron density should be of the order of 10^9 cm^{-3}. The temperature in the region where helium is singly ionized is about 17,000 K. It is possible to estimate the distance of the filaments from the central source of ionizing radiation, if the flux of ionizing photons, the electron density and the value for U_1 are known. Extrapolating the observed UV continuum to wavelengths shortward of the Lyman limit, we estimate the typical distance of the filaments to the central source to be 1 pc. A more realistic model of the broad line region should include tens of thousands of filaments each with a different value for U_1, depending on its distance from the central source. These filaments would cover about 10% of the sky as seen from the central continuum source.

Very little is known about the nature of the central source which provides the energy radiated away directly in the continuum or indirectly in the emission lines. From the variability of the continuum, its size must be smaller than 30 light days, much smaller than the distance to the broad line producing filaments. Fig. 4 shows the distribution of the continuum over a large range of the electromagnetic spectrum. The continuum decreases from the infrared to the soft X-ray region with an overall spectral index of $\alpha = 1$ ($F_\nu \propto \nu^{-\alpha}$). At 6 GHz the object was weaker than 30 mJy, indicating a cut-off somewhere in the mm or cm wavelength range.

There is a jump of a factor of 2 in the flux between the optical and ultraviolet. Because the optical and UV measurements were made only 20 days apart, it is unlikely that such a jump can be explained by the source's variability alone. Low-redshift QSOs often have a bump in their continuum in the spectral range where this jump occurs in Akn 120. Simultaneous optical and UV measurements of Akn 120 are necessary in order to clarify the situation.

NEW FACILITIES AND IMPROVEMENT OF EXISTING INSTRUMENTATION

Fast Photometry – New Facilities at La Silla

H. Pedersen, ESO

The standard photometric equipment at La Silla has 1 second of time as the shortest integration time. This is fully sufficient for most observing programmes. There are, however, several kinds of phenomena which have timescales of about a second or shorter. Among the fastest phenomena, one could mention the optical outbursts of the X-ray bursters (see *The Messenger* No. **18,** 34) or occultations of stars by objects in the solar system.

The astronomer who intends to do such observations will normally need to know the absolute time of each single integration, at least to an accuracy corresponding to the duration of the integration. Various computer programmes and pieces of hardware have hitherto been accommodated to the needs of the La Silla observers, but so far, all timing information had to rely on calibrations using radio signals, e.g. the WWV time-signals at 15 kHz.

The availability of an atomic-beam clock on La Silla (*The Messenger* No. **16,** 11) prompted us to design a new set-up for doing "fast photometry". As soon as the basic principles of operations had been defined, Messrs. D. Hofstadt and F. Gutierrez started programming. Within 10 days they had completed a programme of about 2000 lines of assembler code—without an error. Immediately thereafter, the programme, with its associated hardware, was taken into use both at the 3.6 m and the Danish 1.5 m telescopes.

The fastest data-taking rate is 1 kHz, but any integer multiple of 1 ms can be used as integration time. The photomultipliers interchangingly feed two sets of counters, one set being read while the other is counting. Thereby, the loss of time between two successive integrations can be kept very short—of the order of nanoseconds. Each single integration—from up to four photomultipliers—is written on magnetic tape for later analysis. An on-line pen recorder shows the signal strength in two of the channels. The time resolution of the pen recorder can be selected as any integer multiple of the integration time.

The programme is controlled from a Hewlett Packard terminal. From there, the observer selects integration time and