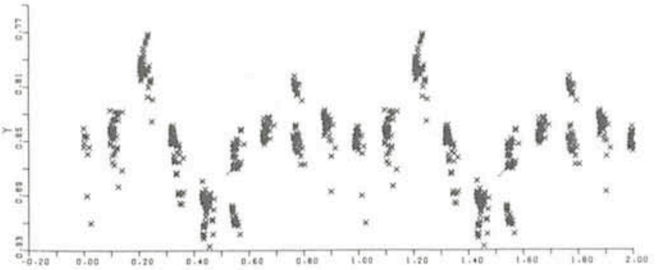

Fig. 5: *The lightcurve of HD 77581 in the Strömgren y passband.*

coordinates, temperature and acceleration of gravity. The radiation emitted towards an observer—situated at a very large distance—is computed by simply adding the contributions from all visible surface elements. A lightcurve is obtained by repeating this final step for different positions of the star in its orbit, with respect to the observer.

In the lightcurve synthesis programme that was developed by the author the local contributions to the total flux are computed using realistic model atmospheres. This programme generates lightcurves for the Strömgren uvby and for the Walraven VBLUW photometric passbands (figure 4). Computations show that the shape of the lightcurve, and in particular the amplitude of the variations, are mainly determined by (1) the ratio q of the mass of the neutron star to that of the optical component (rather than the masses themselves), (2) the ratio r of the mean radius of the star to the binary separation, and (3) the inclination angle i. The parameters q and r determine how much the star is distorted.

In order to find their numerical values in the case of a real-life X-ray binary, we vary these three parameters until an optimal agreement is obtained between the calculated and observed lightcurve of the star.

The value of q is already available for HD77581/0900-40 from the radial velocity and X-ray pulse measurements ($q = 0.076$). Using the amplitude of the lightcurve of this system (figure 5) we were able to derive a reliable constraint for the inclination angle: the value of i is between 75 and 90 degrees, i.e. less than 15 degrees from the line of sight. Therefore, the most probable value for the mass of the neutron star in this system is 1.74 solar masses. It was also found that the supergiant HD77581 almost completely fills its critical lobe.

We would like to apply a similar analysis to the lightcurves of other X-ray binaries, including those systems where q is not very well known. It will be clear that we need very accurate observed lightcurves in order to obtain reliable constraints on the system parameters. From figure 1 it can be seen that many observations are needed to determine an average lightcurve, because of the considerable intrinsic scatter. Therefore, a long-term observing programme is in progress on La Silla to obtain accurate multicolour lightcurves of Galactic and Magellanic-Cloud sources. These observations are made by astronomers from ESO and from the University of Amsterdam with the Dutch 90 cm telescope and Walraven photometer.

Image Processing at the Astronomical Institute of the Ruhr-Universität Bochum

T. Kreidl, M. Buchholz, Ch. Winkler

Image processing of astronomical photographs or, in general, one- and two-dimensional data, play a larger and larger role in the reduction of observations. Several institutes in Europe are acquiring their own hardware and, more recently, an effort to exchange the associated programmes, the software, has been initiated. At the Astronomical Institute of the Ruhr University in Bochum, image processing is already well developed, as explain Drs. T. Kreidl and M. Buchholz together with graduate student Ch. Winkler in this review of the Bochum system.

The Need for Image Processing

Image processing has been in existence now for many years and has been employed in numerous areas before astronomers began to make use of the possibilities offered by its methods. Radio astronomers, having no actual photographs to look at, were forced to turn to numerical methods of handling their data; as the number of observations increased, improved methods became essential to deal efficiently with the enormous number of measurements on hand. Optical astronomers found themselves in similar situations as soon as certain manipulations of their original data became necessary, such as the transformation of densities on a photographic plate into intensities.

When electronic detectors began to come into use, methods had to be worked out to apply geometric corrections, to correct for image defects, and—when no permanent picture was retained—to have the possibility to view and work with the reconstructed image of the digitized data. As fainter and fainter images started to preoccupy the interest of many astronomers, ways to bring out the contrast in objects, remove noisy backgrounds and sum a number of identical images—to mention just a few—became necessary.

In short, an image-processing system should serve to deal with large amounts of pixels in an efficient manner, to work interactively with the image, and provide the means to view, correct, compare and derive meaningful information by utilizing the statistical contents of the measurements to make visible information that would normally remain undiscerned. Obviously, it is not possible to derive more from measurements that is inherently present, and in this regard care must be taken when manipulating data so as to pre-

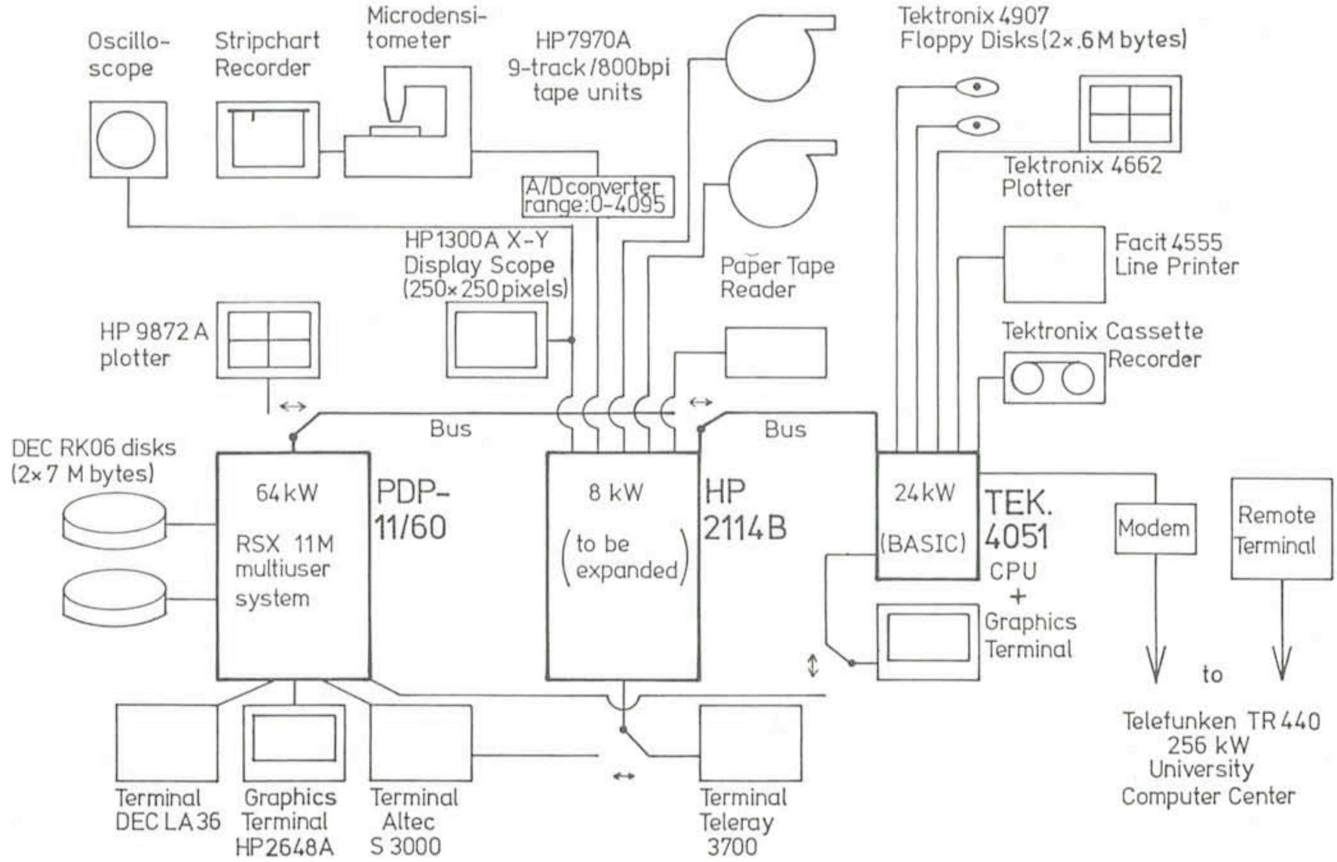

Fig. 1: *The computational facilities at the Astronomical Institute, Bochum.*

vent the loss of information, but also to avoid overinterpretation.

A number of facilities for image processing are in use at our institute and are described here (see figure 1).

Computing Facilities

Microdensitometer: Digitized images can be created directly with the institute's microdensitometer. This instrument, constructed by the Zentralwerkstatt Göttingen GmbH, was originally used for registering stellar spectra. The mounting of a measuring scale and micrometer screw to position the plate in the direction perpendicular to the scan direction (minimum step = 5 μm) enables the user to create, semiautomatically, two-dimensional digitized images, the maximum plate size being 24.5 x 24.5 cm. The dimensions of the slit can be adjusted continuously in a wide range (rectangular as well as square configurations), the minimum area of the slit being limited only by the granularity of the emulsion of the plate.

One example of an object is R 136, which was scanned by slits varying from 10 x 10 μm in the inner, to 40 x 40 μm in the outer regions (Feitzinger et al., 1979). For details on the results, see the article by J. V. Feitzinger and Th. Schmidt-Kaler on page 37. The digitizing of wide angle photographs of the Milky Way (Schlosser et al., 1977) were produced by using a 100 x 100 μm or 200 x 200 μm slit.

After the light has passed through the optics of the instrument, it reaches a photomultiplier, and the signals are sent to the HP2114B computer via an A/D converter. The measured signals of a scanned row are then stored as a record of 12-bit words on magnetic tape. The X-dimension of the scanned image is primarily limited by the storage capacity of the HP2114B, but a memory expansion is being added. Until now, digitized images of up to about 65,000 pixels have been produced. The subsequent data reduction can be undertaken on the HP2114B, Tektronix 4051, PDP-11/60 or at the university's computer centre.

HP2114: It may be surprising that the smallest of these computers, the Hewlett Packard 2114B with only 8 kW of memory, is connected to the other computers, but this is easily explained. The HP was the first computer in our institute and it is now more than ten years since it was installed together with two magnetic tape units, a simple terminal and an X-Y display with 250 x 250 pixels. Even in those "early" days of computing it was thus possible to display and, in a limited way, to process images, as for instance spectra, two-dimensional surface photometry of the Milky Way and measurements obtained with the spectrum scanner used on the 61 cm Bochum telescope on La Silla.

It should be noted that the X-Y display is by no means comparable to a modern graphics display; it possesses no more intelligence than an ordinary oscilloscope, which means that every point has to be programmed—not an easy task for alphanumeric characters. Now, with the graphic capabilities of the Tektronix 4051 and the terminal HP2648A, the old HP computer is only used as a buffer and a controller for the magnetic tape units, paper tape reader and the analog-to-digital converter. But, nevertheless, there are still users of this little machine, which is at least reliable and certainly will profit greatly from the above-mentioned memory expansion.

Tektronix 4051: This graphics system forms an additional facility for data reduction and analysis. Several elements make up the system, the primary ones being the Tektronix 4051 computer with extended memory (programmable in BASIC) and a high-resolution CRT (1024 x 780 points). Data and programmes can be stored on magnetic tape cassettes holding up to 300 kbytes. Additional peripherals include a Tektronix 4907 file manager (a direct access 600 kbyte disk device for storage and retrieval of ASCII and binary data and programmes), a Tektronix interactive digital plotter and a FACIT printer.

An RS232C interface enables the user to operate the Tektronix 4051 as an I/O terminal of the PDP-11/60 or the Telefunken TR440 of the university's computer centre. For data transfer to the HP2114B, an IEC bus interface is provided.

Several software routines have been developed for the 4051 system, including a pseudo three-dimensional plot of an image (Feitzinger et al., 1979 op. cit.), contour maps and several reduction programmes (characteristic curves, etc.).

PDP-11/60: With the installation in January 1979 of a PDP-11/60 with 64 kW of memory, floating-point processor, and dual RK06 disk drives, the possibility of doing interactive image processing became feasible, the turnaround time being an important factor. The link to the HP2114B was established with an IEC bus, the PDP-11 being controller. The bus is also used to operate a four-colour HP9872A flatbed plotter. Two graphics terminals are available: the Tektronix 4051 and HP2648A. The latter can be switched into scaled compatibility mode, allowing it to operate with Tektronix graphics software.

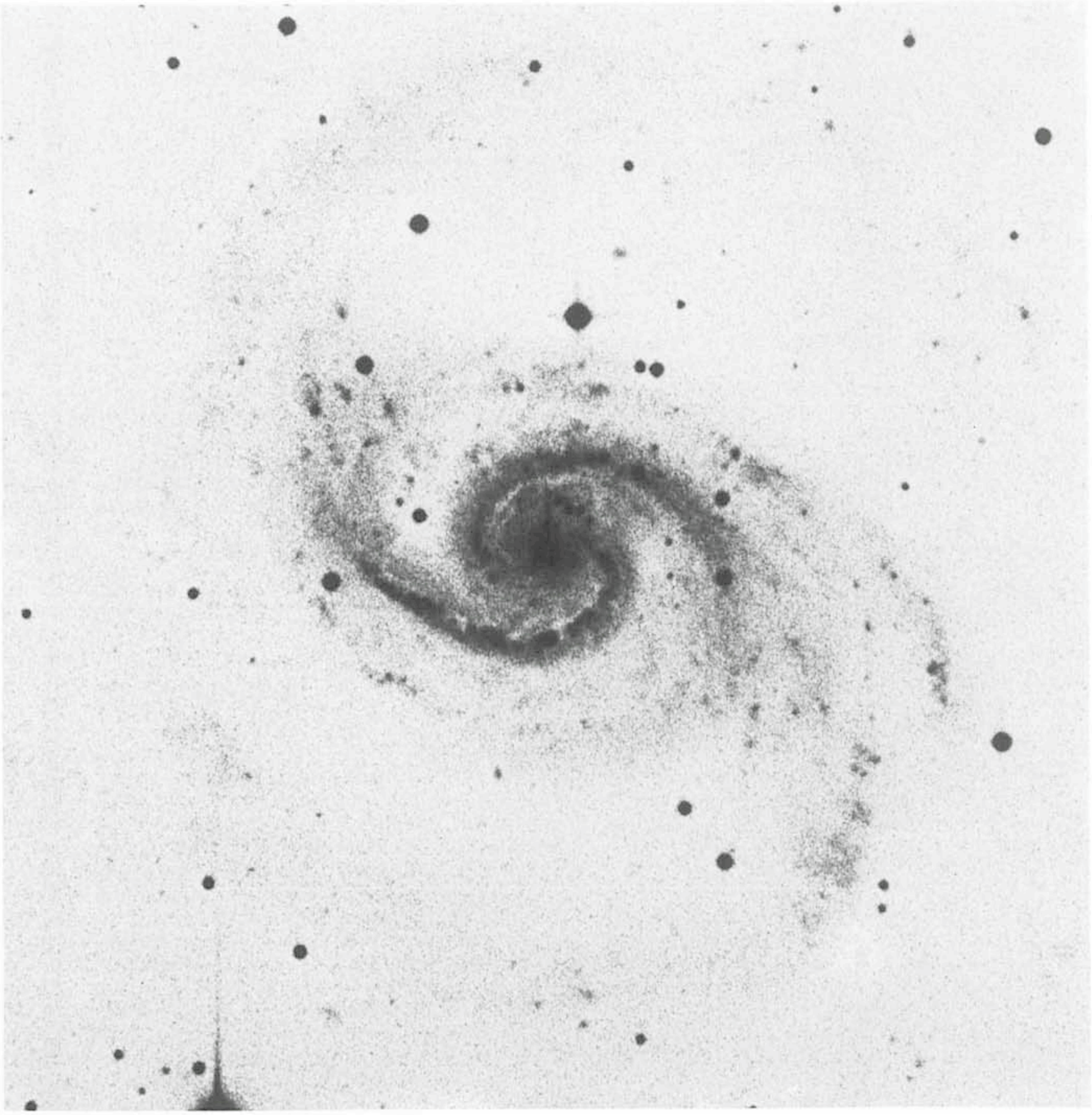

Fig. 2: *NGC 1566 as reproduced from the ESO(B) Atlas.*

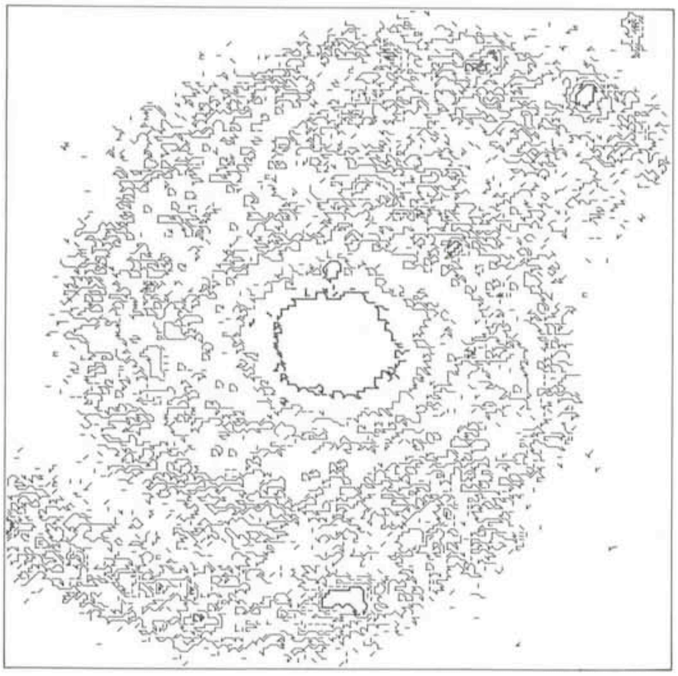

Fig. 3: *Contour map of the original digitized data.*

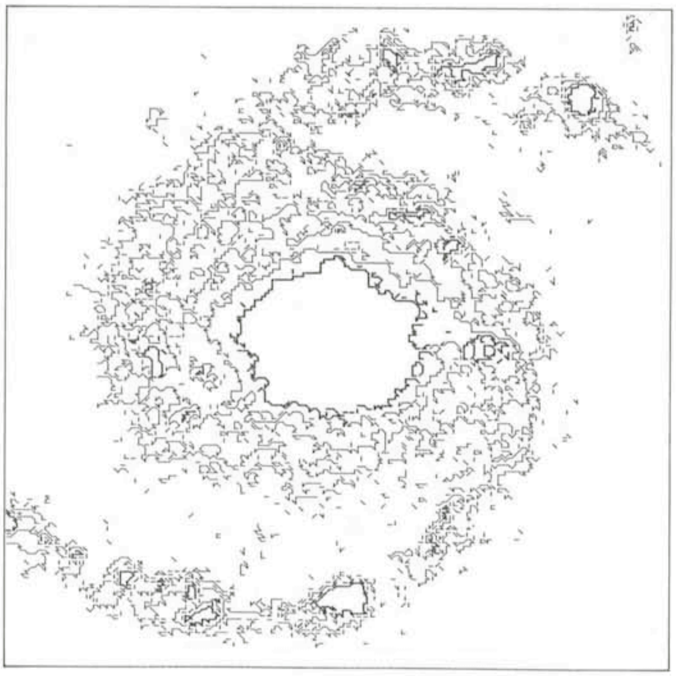

Fig. 5: *The same image as in figure 4, but with different levels chosen to emphasize the features in the arms.*

The Software

The heart of the image processing facilities is the software of the Tololo-Vienna system, developed by S. Schaller of CTIO and R. Albrecht of the Institute for Astronomy, Vienna, Austria. Application programmes have been developed primarily at these institutes; but after they have been obtained by other institutes, people there have become involved in programme development for the system as well. Through the generous help of R. Albrecht and A. Schermann of Vienna, it was possible to transfer the entire system to Bochum in September 1979. Details of the system itself can be found elsewhere (see, for example, Albrecht, 1979).

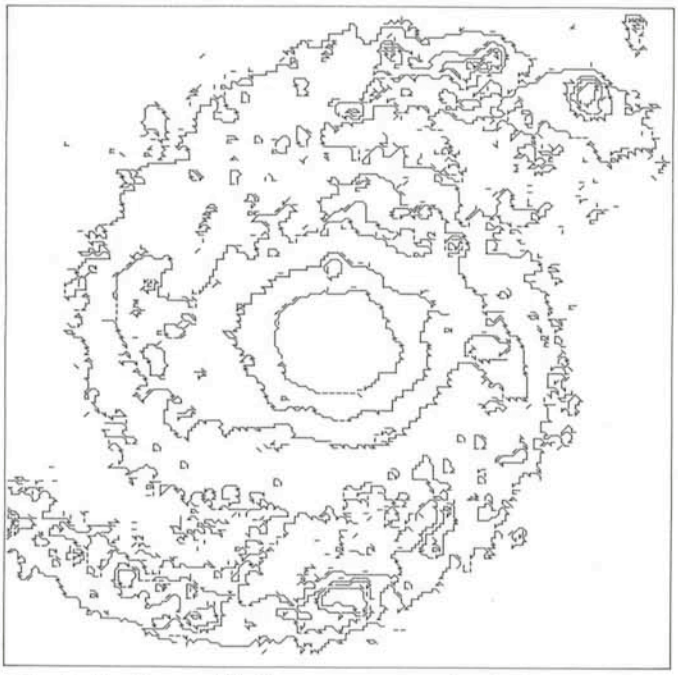

Fig. 4: *As above; with the same contour levels, but smoothed.*

One- and two-dimensional images can be handled very efficiently and interactive work can be realized with relatively short computation times needed for the simpler operations. Moreover, more than one user can work simultaneously. There are already over one hundred application programmes and with the system being open-ended, new routines are continuously being developed. It was already possible to adapt several plotting routines for use on the HP9872A plotter.

The normal procedure is to send data contained on magnetic tape to the PDP-11 via the bus, which are subsequently stored on disk, modified structurally for integration into the TV-system file structure, and incorporated into the system with the appropriate application programme.

A Working Example

An example of the Tektronix 4051 system's capabilities has already been demonstrated with R 136. Here, we would like to show some of the capabilities as achieved with the PDP-11 and the TV-system. As an object, the Seyfert galaxy NGC 1566 was chosen. A photographic reproduction is shown in figure 2. The digitization of the inner part of this object and the data transfer took place as described above, with 195 x 195 pixels obtained with a 30 x 30 μm slit.

Figure 3 shows the raw data in a pseudo-contour plot. The dynamic range of the image was then scaled down by a factor of two and smoothed with a 3 x 3 pixel filter, utilizing the sigma-kappa method (cf. Newell, 1979).

The suppression of noise can easily be seen in figure 4, which shows the result of these actions. The contour levels are the same as in the previous figure. To bring out details, the image was plotted again (fig. 5) with contour levels chosen so as to emphasize the features in the arms. The clearly developed spiral arms running right into the centre and the extremely narrow dust lanes, interrupted by H II regions, can be seen. Essentially the same details can be seen as in figure 4 of de Vaucouleurs' study of this object (de Vaucouleurs, 1973), his contours being obtained with the McMath-Hulbert Observatory's isophotometer. Finally, figure 6 shows a ruled surface plot of the data. The segmentation of the arms and the compact nucleus are well depicted.

As the future tendency seems to lean towards even larger amounts of digitized data (e.g. from IUE, Space Telescope, CCD detectors, etc.), appropriate facilities will play an even more important role when dealing with this information. With the number of individuals involved in image processing here, the further expansion and refinement of the systems available seems to be justified and many plans for future improvements are being considered.

Acknowledgements:

The help of Drs. R. Albrecht and A. Schermann of the Institute for Astronomy, Vienna, and the administration and staff of CTIO are gratefully acknowledged for the possibility of obtaining the TV-system. Transfer was made possible by the Max-Planck Institute for Astronomy, Heidelberg, for which one of us (TK) would like to thank Dr. H.-J. Röser and R. Tremmel. We would also like to thank Dr. J. V. Feitzinger for conveying to us information on NGC 1566 prior to publication.

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Schlosser, W., Schmidt-Kaler, Th., 1977: *Vistas in Astronomy,* **21,** 447.
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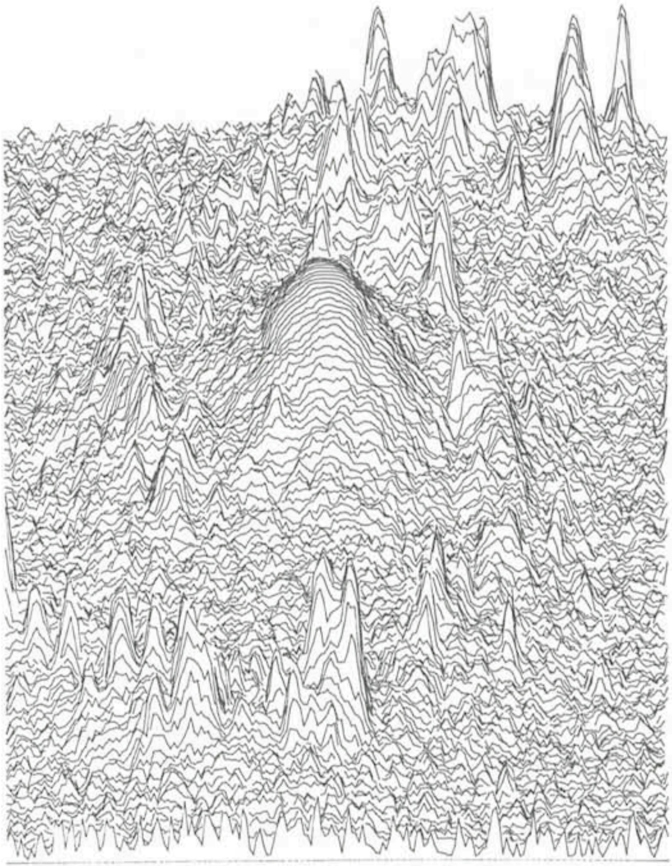


Fig. 6: *A hidden line plot of the smoothed data of NGC 1566. Note the high contrast of the arm structure.*

NEWS AND NOTES

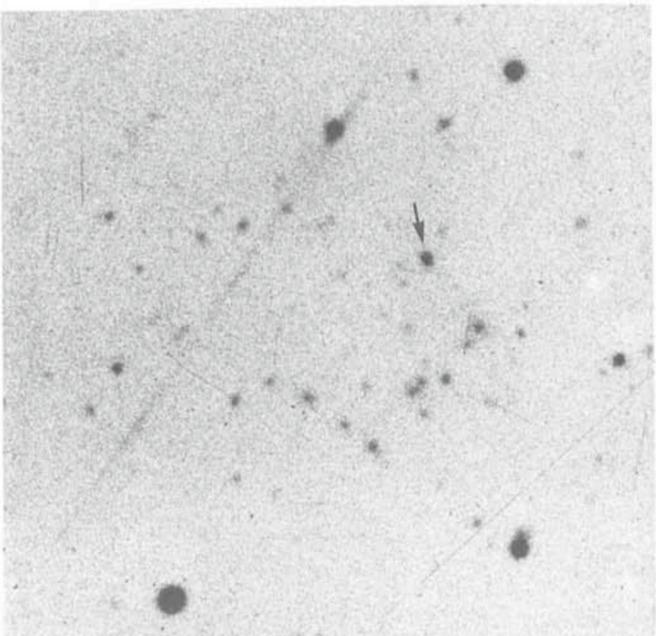
When the Earth was Born

Astronomy offers the unique possibility of looking back in time. Contrary to other sciences, it allows us to see objects as they were a long time ago. This is of course due to the enormous distances in the Universe and the finite velocity of light: around 300,000 km s^{-1}.

With the availability of very deep, red plates from the ESO Schmidt telescope for the red part of the joint ESO/SRC Atlas of the Southern Sky, a group of astronomers has now begun to look for very distant clusters of galaxies. A substantial number of hitherto unknown clusters have been discovered and some of them are in the process of being investigated further.

We here show just one example. A cluster was discovered by Dr. I. Semeniuk two years ago (actually on the SRC J plate). Last month, it was possible to obtain a spectrum of the brightest galaxy in this cluster (see the figure) by means of the new Reticon spectrograph at the Cassegrain focus of the 100-inch du Pont telescope at the Las Campanas observatory. Thanks to the excellent telescope and the powerful spectrograph, it was possible to measure the position of several absorption lines in the spectrum of the $20^m.5$–$21^m.0$ elliptical galaxy (no emission lines were present) and to determine the redshift as z = 0.30. The total observing time was just two hours.

Applying the relativistic correction, and under the assumption that the redshift is a result of motion of this object (Doppler effect),



A blue 3.6 m photo of the very distant cluster 0346–454, obtained under mediocre seeing conditions. A faint artificial satellite crossed the field during the exposure. The galaxy for which a spectrum was obtained as described in the text has been indicated.