confirmed by a more detailed analysis of all three infrared frames.

The physical interpretation of the observed extended nuclear IR emission of IC 5063 is again complicated by the presence of emission lines in the three observed infrared bands. A separation of the line and continuum contribution requires narrower pass bands. Such narrow bands can be realized with the circular variable filter (CVF) of the IRAC camera. However, the detector noise of the present array limits this mode of operation to relatively bright objects. From published IR line fluxes only the nearby Seyfert 2 galaxy NGC 1068 appeared to be bright enough to attempt CVF observations. As this galaxy also belongs to the AGNs with evidence for a hidden core (cf. [8]) NGC 1068 was also included in our programme.

Our broad-band IR images of NGC 1068 show qualitatively similar properties as the IC 5063 frames. We again observe a bright unresolved nucleus surrounded by extended emission. Surprisingly, our narrow-band CVF images in line-free IR continuum bands turned out to be quite different. These images show the unresolved central nucleus but practically no detectable continuum radiation from an extended circumnuclear region. On the other hand, as demonstated by the Brackett-gamma line image reproduced in Figure 6, in the light of the IR emission lines we clearly see also extended emission surrounding the nucleus. Hence, in the case of NGC 1068 it seems clear that at least most of the extended circumnuclear IR emission is caused by line emitting gas.

Our results for NGC 1068 clearly demonstrate the potential of narrow-band IR imaging for studies of nearby AGNs. Hopefully, improved array detectors and larger telescopes will make it possible to apply this technique in the future also to other active galaxies including the hidden cores discussed in the first chapters of this paper.

References

[1] van Gorkom, J.H., Kotanyi, C.G., Tarenghi, M., Véron-Cetty, M.P., Véron, P.: 1983, *The Messenger* **33,** 37.
[2] Appenzeller, I., Östreicher, R.: 1988, *Astron. J.* **95,** 45.
[3] Wagner, S.J., Appenzeller, I.: 1988, *Astron. Astrophys.* **197,** 75.
[4] Wagner, S.J., Appenzeller, I.: 1989, *Astron. Astrophys.* **225,** L13.
[5] Schommer, R.A., Caldwell, N., Wilson, A.S., Baldwin, J.A., Phillips, M.M., Williams, T.B., Turtle, A.J.: 1988, *Astrophys. J.* **324,** 154.
[6] Moorwood, A.: 1988, *The Messenger* **52,** 50.
[7] Moorwood, A., Finger, G., Moneti, A.: 1988, *The Messenger* **54,** 56.
[8] Antonucci, R.R.J., Miller, J.S.: 1985, *Astrophys. J.* **297,** 621.

A Redshift Survey of Automatically Selected Clusters of Galaxies

L. GUZZO[1], R. NICHOL[2], C. COLLINS[3], S. LUMSDEN[4]

[1]Osservatorio di Brera, Milan, Italy; [2]Department of Astronomy, University of Edinburgh, Great Britain; [3]Royal Observatory, Edinburgh, Great Britain; [4]Astrophysics Group, Imperial College, London, Great Britain

Introduction

The study of the large-scale structure of the universe provides direct constraints on the initial form of the density fluctuations from which galaxies, clusters and superclusters formed. This can be achieved by mapping the large-scale galaxy distribution, with the assumption that light is a good tracer of the underlying mass distribution. To compare our maps with the theory, we need to extract some numbers describing their properties in a statistical sense. One of the main properties which are of interest in this sense is *clustering,* i.e. how the distribution of objects differs from a random sample. This is of great importance, since theories usually give precise predictions about the level of clustering on different scales.

The most popular statistical estimator of clustering is certainly the two-point spatial correlation function $\xi(r)$, that measures the probability in excess of random of finding two objects at a separation r (see Peebles, 1980). One of the most remarkable results obtained in the last few years is that the two-point correlation function for clusters of galaxies (ξ_{cc}) is about 15 times stronger than that for galaxies (ξ_{gg}) (see Bahcall, 1988). This observation is one piece of evidence that has prompted the idea of biased galaxy formation (Kaiser, 1984) and indicates that neither galaxies nor clusters can both be tracers of the mass distribution. In the context of models of galaxy formation the "standard cold dark matter" model (CDM) fails to provide enough power on cluster scales when normalized to fit the observed ξ_{gg} (White et al., 1987).

Given the prime importance of this observation, it is extraordinary that we still rely on estimates of the cluster correlation function based on "eyeball" catalogues of clusters, namely the Abell (1957) and Abell, Corwin, Olowin (ACO, 1989) lists. Evidence has been accumulating about systematic and unquantifiable selection effects present in such visual compilations, giving rise to doubts on the reality of the observed ξ_{cc} (Sutherland, 1988, and see Dekel, 1989 for discussion). With these uncertainties in mind, the estimation of ξ_{cc} from a redshift survey of objectively (i.e. automatically) detected clusters is long overdue. In 1988 we started at ESO a redshift survey based on an automatic sample of rich clusters extracted from the Edinburgh/Durham Southern Galaxy Catalogue. The results (so far) have been very successful, and in this note we would like to report on the present status of the project.

The Automatic Catalogue of Clusters

As mentioned, the cluster catalogue has been extracted from the Edinburgh/Durham Southern Galaxy Catalogue (EDSGC), one of the first ever large-scale machine-based optical galaxy catalogues. This galaxy survey has been constructed using the COSMOS high-speed microdensitometer, and consists of 60 UK Schmidt J survey plates centred at the South Galactic Pole. The galaxy catalogue covers an area of 0.5 steradians to a limiting magnitude of $b_j = 20$, with a total of ~ 1.5 million galaxies, with $> 95\%$ completeness and $< 10\%$ star contamination (see Heydon-Dumbleton, Collins and MacGillivray, 1989 for details). The EDSGC represents an ideal

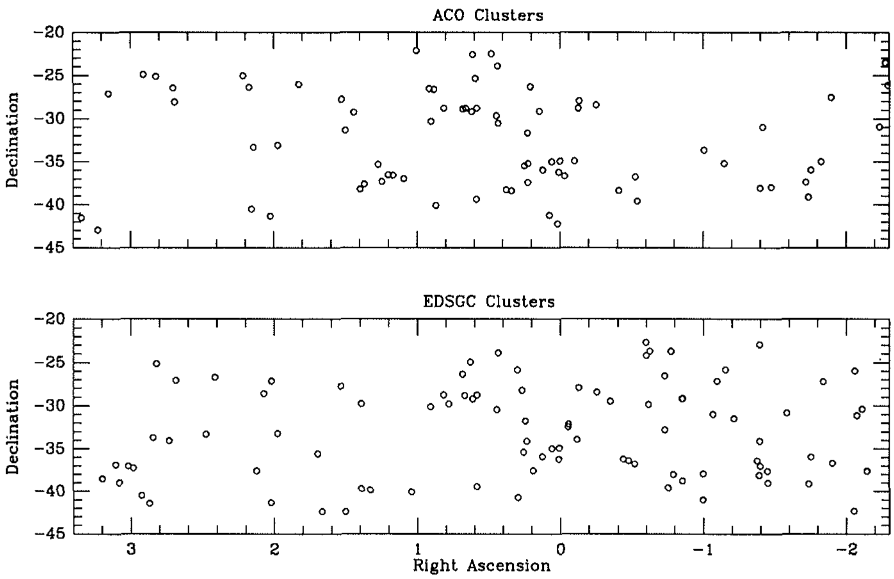

Figure 1: *Comparison of a subset of the EDSGC automatic cluster catalogue with a similar subset in the same area extracted from the ACO catalogue. Both subsets correspond to Abell distance classes ≤5. For the comparison of richness classes see the text.*

database for producing a cluster catalogue.

The first step in constructing our cluster catalogue was to produce a list of candidate clusters. The galaxy data were binned into 5 arcmin pixels and then smoothed with a gaussian filter to reduce the harshness of the binning. To avoid preferentially detecting clusters in high-density regions of the survey while missing others in low-density regions, we must remove the large-scale galaxy distribution. This was achieved by heavily smoothing the pixel data with a median filter on the scale of 1.5 degrees and then subtracting this sky background estimate. Projection effects have been proposed to account for part of the discrepancy between ξ_{gg} and ξ_{cc}. We took particular care then to reduce their influence by deblending the candidate clusters. Each of them was rethresholded at 16 equal levels above the local sky background as estimated above. If any saddle-points in the candidate's pixel data were found, the candidate was then split into its daughter members. After the completion of the redshift survey we will be able to check residual projection effects by deblending in 3 dimensions, using the magnitude and redshift distribution of the cluster members. The total number of candidate clusters detected over the 1700 deg^2 of the EDSGC survey is ~1000 (Nichol et al., 1990).

Abell estimated the distance to a cluster using the magnitude of the tenth brightest member (m_{10}). The cluster's richness was defined as the number of galaxies within a fixed radius (scaled to the cluster distance) in the magnitude range between m_3 and m_3+2. Our first candidate analysis was the same as Abell, as any new cluster catalogue must be initially compared to the Abell (or ACO for the South) catalogue. The final catalogue contains ~300 clusters with >30 members. Of these 65% are present in the ACO catalogue, yet we only detect 30% of the ACO's clusters in our survey region. Upon checking the missing ACO clusters we find they are of low richness, or not a cluster at all, while the new non-ACO clusters are all rich bonafide clusters. The clusters common to the two catalogues show slight distance correlation but we find no relationship between our richness and ACO richness. In Figure 1 we show a plot of the sky distribution of the Automatic Clusters (AC), while Figure 2 shows an EFOSC direct image of the central regions of the new cD cluster AC-22.

Observational Strategy

In 1987 while the construction of the cluster catalogue was in its early stages, we realized how efficiently we could construct a cluster redshift survey by using EFOSC in MOS mode at the ESO 3.6-m telescope. We intended to observe around 10–15 galaxy redshifts per cluster on a sample of about 150 clusters and for this EFOSC was more suited than OPTOPUS, the fiber large-field multi-object facility. Indeed, with this number of spectra and with a good filling factor of the CCD field (as it is the case for most of our clusters) the use of EFOSC is to be preferred to OPTOPUS both in terms of efficiency and flexibility. On the other hand, OPTOPUS is best suited to investigate in detail problems like subclustering, where many redshifts are needed on every single cluster. In this sense, our programme is complementary to the key programme of Mazure et al. (1989), where the emphasis is more on studying detailed structure.

The observing programme was started in August 1988, with a first allocation of 3 nights at La Silla, and received generous attention from the OPC in the following semesters, especially as we did not ask for the official long-term (i.e. key programme) status. The total number of nights allocated so far is 12, over four semesters. During these two years of use, EFOSC has proved to be an excellent device for this kind of redshift survey. With some good luck with the weather, we could observe at high efficiency about 75% of the time. We covered 62 clusters, with a total of ~800 galaxy spectra.

The observational set-up of EFOSC includes the B 300 grism, providing a spectral coverage from 4000 Å to 7000 Å with about 6 Å/pixel. The use of the cross-correlation technique to measure the redshift reduces the actual rms errors to 50–100 km/s, depending on the S/N ratio of the spectra. With 10–15 measured galaxies per cluster we have negligible errors on the mean redshift (<200 km/s). Exposure times of 20 to 30 minutes have been used to obtain good S/N spectra for the faintest objects ($b_j = 19$) observed. Accurate positions (<2″), magnitudes (<0.2) and image classification for all the objects in

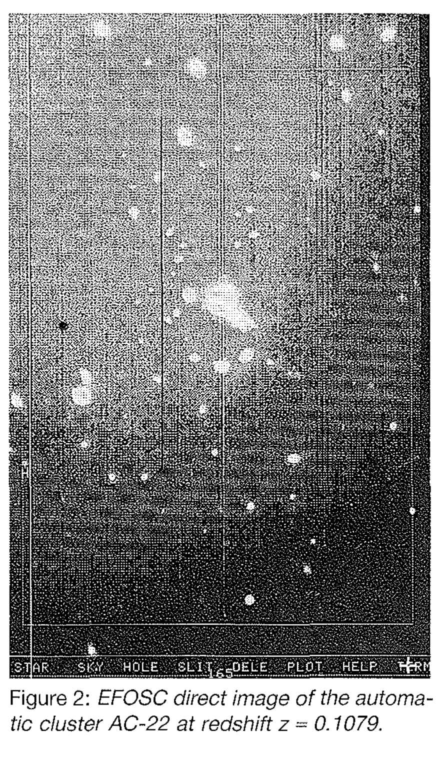

Figure 2: *EFOSC direct image of the automatic cluster AC-22 at redshift z = 0.1079.*

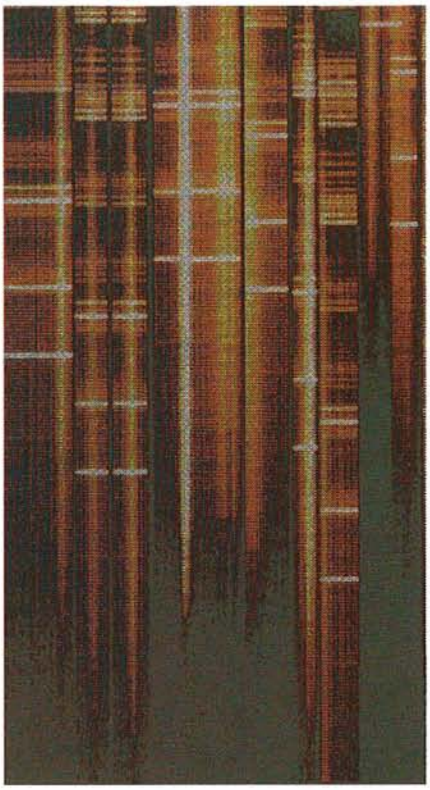

Figure 3: *MOS frame of galaxies in the field of AC-22. The quality of cosmic ray events elimination through AVERAGE/WINDOW is evident.*

each cluster, all information provided in the EDSGC, have proved to be very useful to maximize efficiency. We can produce high-quality finding charts and decide well in advance where the areas best suited for MOS are in each cluster. In this way we decide the optimal position angle of the rotator for including as many spectra as possible on the CCD frame.

Mask preparation with PUMA has proved to be quite simple. After some practicing we decided to use quite short slitlets (10 arcsec) to guarantee flexibility during the initial selection of slit positions. This small size allows the spectra to be packed more closely to each other if desired, while on the other hand longer slits can be built by simply overlapping many slitlets. This is much simpler than the standard procedure involving the construction of a different IHAP table for each chosen slit length. A decision on the best length can then be taken directly on the specific area. There is always a compromise between the desire to observe as many objects as possible and the necessity to perform a good sky subtraction, and this compromise is obviously dependent on the surface distribution of objects and on their magnitudes. Figure 3 shows the MOS frame for AC-22.

To increase our global efficiency and reduce the time necessary to complete the project, we decided last year to complement ESO observations using the AUTOFIB fiber system at the 3.9-m Anglo-Australian Telescope. AUTOFIB is similar to OPTOPUS, but with the advantage of having an automatic fiber positioner which greatly improves the observing efficiency. Indeed, during 3 nights in October 1989 we secured another 30 clusters.

Data Reduction

The aspect that makes Multiple Object Spectroscopy so interesting and useful is the tremendous increase in the number of spectra that can be obtained in one night with respect to the standard method. This implies that automatic data reduction techniques become a must to avoid being overwhelmed by the data flow. Future MOS devices will certainly have to include as much on line reduction as possible, otherwise data handling will become prohibitive. For the time being the astronomer has to solve the problem in the reduction phase. Unfortunately, no specific package has been developed for this kind of data inside MIDAS, and therefore we had to construct some routines to extract and handle the single spectra from their parent multi-object frame. This implied an extra effort in the beginning, that however improved enormously the efficiency of later reductions. Presently, reduction has become a routine job and we can transform a whole MOS frame into a set of ~15 1-D calibrated and sky subtracted spectra in about two hours. To wavelength calibrate the single 2D spectra extracted from the MOS frame we use the standard commands in the long-slit context (IPCS in the old MIDAS). In Figure 4 we show a final 1D spectrum from the same cluster of Figures 2 and 3, i.e. AC-22.

The next steps follow essentially the recipe by Tonry and Davis (1979) for an optimal treatment of the spectrum before applying the cross-correlation algorithm. These involve, among others, rebinning into logarithmic bins, elimination of residual spikes (emission lines, residual cosmics and sky lines), continuum subtraction, endmasking and bandpass filtering. Finally, cross-correlation with several galaxy templates is performed using the Fast Fourier Transform method. To calibrate the zero point of the galaxy templates, we have also observed high S/N nearby objects with very good 21-cm redshift determinations.

Future Prospects

With another 5 nights at ESO and a similar amount at the AAT we will be able to complete the first homogeneous sample of about 150 clusters with richness >30 and distance classification ≤5 (with m_{10} in R ≤ 17.2). This will then provide an excellent database for estimating ξ_{cc} with a higher accuracy than previous measurements (Bahcall and Soneira, 1983; Sutherland, 1988).

Apart from the main goal of the survey, i.e. ξ_{cc}, the complete sample of 150 clusters will be used to initiate a number

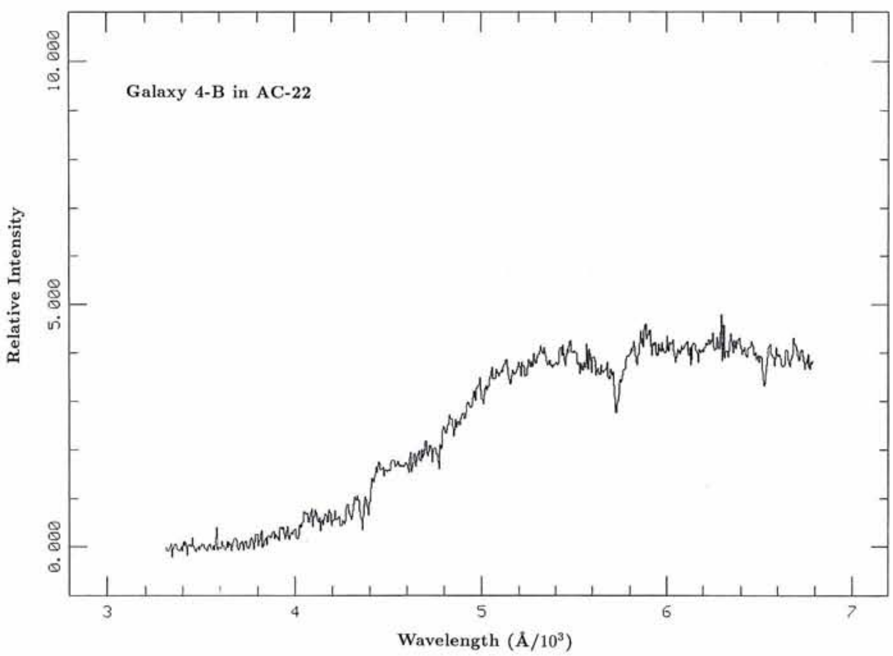

Figure 4: *Spectrum of the 18-magnitude cD galaxy in AC-22 (z = 0.1071). Note the good quality of sky subtraction and the number of absorption features. Total exposure time in this case is 30 minutes.*

of parallel studies. We intend to study: (a) the luminosity function of cluster galaxies (we have b_j magnitudes from the EDSGC) and its relations with the dynamical state of the parent cluster; (b) velocity dispersions and substructure in those clusters with a large enough number of redshifts. These are just some examples of the wealth of scientific information contained in our cluster redshift survey. However, the most exciting results will probably be those we cannot foresee at present, as it has always been the case when new large-scale redshift surveys have been performed.

References

Abell, G.O.: 1958, *Astrophys. J. Suppl.*, **3**, 211.
Abell, G.O., Corwin, H.G. and Olowin R.P.: 1989, *Astrophys. J. Suppl.*, **70**, 1.
Bahcall, N.A.: 1988, *Ann. Rev. Astron. & Astrophys.*, **26**, 631.
Bahcall, N.A. and Soneira, R.M.: 1984, *Astrophys. J.*, **277**, 27.
Dekel, A.: 1989, in proc. Vatican Study Week on *Large-Scale Motion in the Universe*, V.C. Rubin and G.V. Coyne eds., Vatican City, Pontificia Academia Scientiarum – Princeton University Press.
Heydon-Dumbleton, N.H., Collins, C.A., and MacGillivray, H.T.: 1989, *Mon. Not. R. Astr. Soc.*, **238**, 379.
Kaiser, N.: 1984, *Astrophys. J.* (Letters), **284**, L9.
Mazure, A., Katgert, P., Rhee, G., Dubath, P., Focardi, P., Gerbal, D., Giuricin, G., Jones, B., Lefevre, O., Moles, M.: 1989, *The Messenger*, **57**, 30.
Nichol, R.C., Collins, C.A., Guzzo, L., Lumsden, S.: 1990, in preparation.
Peebles, P.J.E.: 1980, *The Large Scale Structure of the Universe*, Princeton, Princeton University Press.
Sutherland, W.: 1988, *Mon. Not. R. Astr. Soc.*, **234**, 159.
Tonry, J., Davis, M.: 1979, *Astron. J.*, **84**, 1511.
White, S.D.M., Frenk, C.S., Davis, M., and Efstathiou, G.: 1987, *Astrophys. J.*, **313**, 505.

Comet Austin Rounds the Sun

R.M. WEST, ESO

Modern astronomers are privileged people. They exert a profession which for many is also their hobby; they receive good support from the authorities; they have the attention of a broad public and they work in a field which in virtually all respects is above political and ecological concerns.

It even appears that they no longer run the risk of being punished when they make imprecise predictions . . . Astronomers nowadays only rarely think of their pitiful eastern colleagues who long ago forgot to predict an eclipse and promptly lost their jobs, heads and lives.

Of course, in the meantime the computations needed to establish the exact time and place of a solar eclipse one hundred years from now have become so accurate that tour organizers may safely start the preparations and book the hotels already now. On the basis of the collective experience gained during several centuries we now master celestial mechanics to a very high degree of perfection and Voyager was guided to within a few kilometres of the aiming point at Neptune, more than 4000 million kilometres away.

Comet Brightness Prediction: A Difficult Art

But such a high degree of perfection is less evident when we turn to the brightness of comets. Indeed, in this field we astronomers have several times been in situations similar to those frequently experienced by our exposed meteorological colleagues, especially before the advent of remote-sensing weather satellites. Why, demanded the angry public, why did we leave our umbrellas at home and got wet when you predicted sunny weather? And why, yes why did you astronomer "experts" say that the comet would become so bright that it could be seen with the naked eye, and then I could hardly find that weak patch of nebulosity in my new expensive telescope, specially bought for this "unique" event?

I do not blame the public reaction, for I have had this experience myself in early 1974 when I tried to locate Comet Kohoutek from a balcony in brightly lit Geneva where I lived at that time. And I had a feeling of "déjà vu" when I searched for Comet Austin in the morning sky from the roof of my home in Munich in late April this year.

In old days, the appearance of comets was always unexpected and it often brought fear to monarchs and other rulers – no doubt that such events were often cleverly interpreted by sly counsellors to their own advantage. These times have passed and in our days the discovery of a new comet, especially one in a near-parabolic orbit and therefore "new" in the sense that it has never before been near to the Sun, rather makes some astronomers worry about how accurate their brightness predictions will turn out to be.

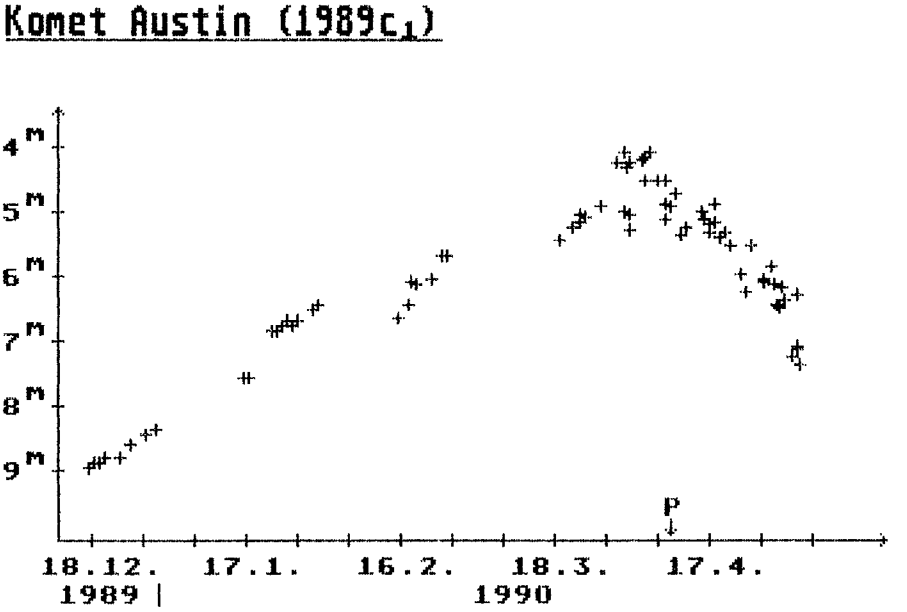

Figure 1: *Heliocentric brightness evolution of Comet Austin, showing the rapid decrease after perihelion. Prepared by Andreas Kammerer (Karlsruhe, Fed. Rep. Germany).*