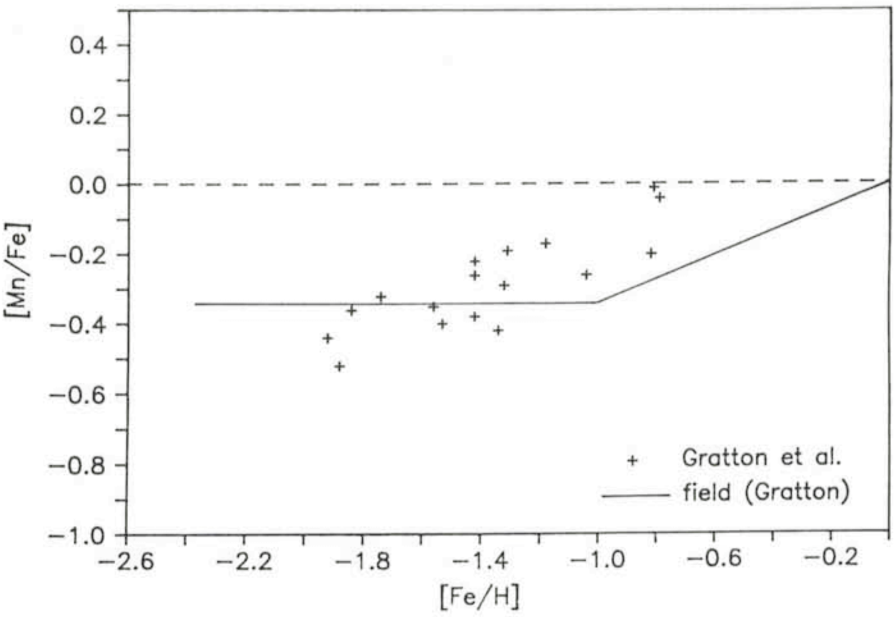

Figure 3: *[Fe/H] vs [Mn/Fe] for globular clusters. The solid line is representative for field halo stars.*

3.6-m telescope on La Silla. These spectra were used to obtain metal abundances which allowed the derivation of a highly accurate metallicity scale for globular clusters. The good correlation existing between metal abundances obtained from these spectra and photometric indices like Q_{39} (Zinn and West, 1984) is shown in Figure 2.

I performed an analysis similar to that made for the field halo stars on these spectra. There are three good Manganese lines, near 6000 Å, in these spectra. Mean abundances for seventeen globular clusters were thus obtained. The results are displayed in Figure 3, which is analogous to Figure 1; each point represents a globular cluster. The mean results for field halo stars are also displayed here. Like field halo stars, also globular cluster stars exhibit an enhanced odd-even effect with respect to population-I stars, approximately by the same amount (~0.3 dex) as field halo stars. However, the results suggest that Manganese is more and more deficient as metallicity drops in globular clusters. If confirmed by more extensive results, this fact suggests a systematic difference in the nucleosynthesis processes in globular clusters and field halo stars.

References

Barbuy, B.: 1988. *Astron. Astrophys.* **191,** 121.

Beynon, T. G. R.: 1978. *Astron. Astrophys.* **64,** 145.

Booth, A. J., Shallis, M. J., Wells, M.: 1983. *Monthly Not. Roy. Astron. Soc.* **205,** 191.

Booth, A. J., Blackwell, D. E., Petford, A. D., Shallis, M. J.: 1984. *Monthly Not. Roy. Astron. Soc.* **208,** 147.

François, P.: 1988. *Astron. Astrophys.* **195,** 226.

Gratton, R. G.: 1988. In *Stellar Evolution and Dynamics of the Galactic Halo,* M. Azzopardi and F. Matteucci eds., ESO, Garching, 153.

Gustafsson, B.: 1988. In *Stellar Evolution and Dynamics of the Galactic Halo,* M. Azzopardi and F. Matteucci eds., ESO, Garching, 33.

Helfer, H. L., Wallerstein, G., Greenstein, J. L.: 1959. *Astrophys. J.* **129,** 700.

Lambert, D.: 1987. *J. Astrophys. Astron.* **2,** 103.

Magain, P.: 1987. *Astron. Astrophys.* **179,** 176.

Matteucci, F.: 1988. In *Stellar Evolution and Dynamics of the Galactic Halo,* M. Azzopardi and F. Matteucci eds., ESO, Garching, 609.

Sneden, C.: 1985. In *Production and Distribution of C, N and O Elements,* J. Danziger, F. Matteucci and K. Kjär eds., ESO, Garching, 1.

Spite, M., Spite, F.: 1985. *Ann. Rev. Astron. Astrophys.* **23,** 225.

Zinn, R., West, M. J.: 1984. *Astrophys. J. Suppl.* **55,** 45.

Chemistry at High Galactic Latitudes: CH, CH^+ and CN Absorption Lines

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Introduction

The molecular clouds detected at high galactic latitudes by Magnani, Blitz and Mundy (1985) through CO line emission at 2.6 millimetre have attracted a lot of attention. They are particularly interesting because most of them appear to lie within the hot, local ($d \leq 150$ pc) interstellar medium, where they may be condensing out of loops and filaments of atomic hydrogen (Blitz 1988). The clouds can also be characterized by their optical obscuration, and by their emission at 100 μm as seen by IRAS (de Vries and Le Poole 1985; Désert, Bazell and Boulanger 1988).

Although a considerable amount of data has been gathered over the past few years on the global properties and morphology of the clouds, still little is known about the physical and chemical state of individual clouds. Because the high latitude clouds are embedded in a different environment, it is intriguing to ask to what extent they differ from the "classical" diffuse clouds (such as the ζ Oph or ζ Per clouds), or the "classical" dark clouds (such as the Taurus molecular cloud TMC 1 or L 134 N). For example, the high latitude clouds have low visual extinctions, $A_v \approx 1-2$ mag, similar to those of the diffuse clouds that have been studied extensively by optical absorption line observations; yet their strong CO millimetre emission is much more characteristic of that found in dark clouds. Are the abundances of other simple molecules also enhanced in high latitude clouds compared with diffuse clouds? If so, what process is causing this enhancement?

Observations and Results

In order to investigate this question, we proposed to search for molecular absorption lines in Southern high latitude clouds using the Coudé Echelle

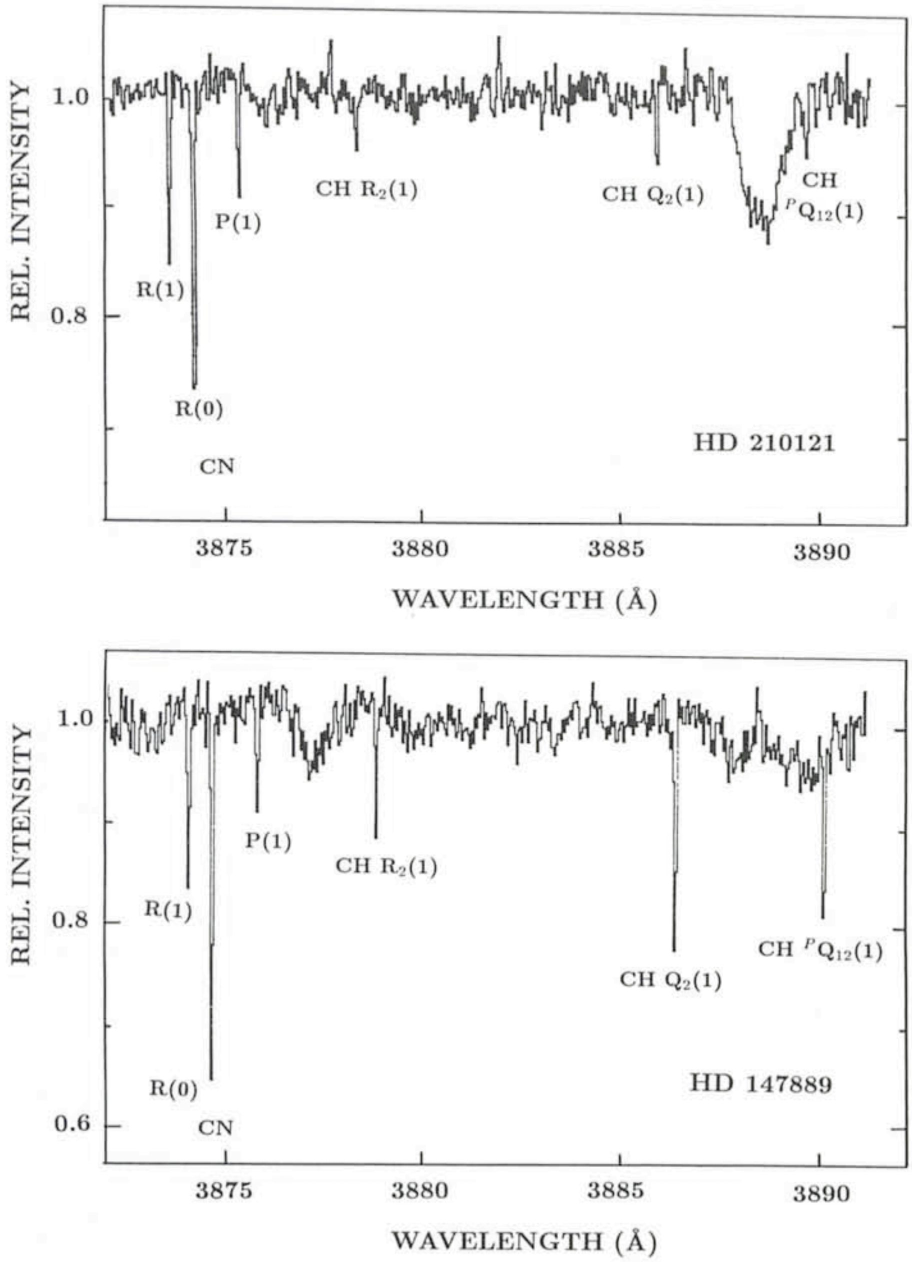

Figure 1: *Absorption spectra of HD 210121 and HD 147889 in the wavelength region of the interstellar CN and CH absorption lines. The line of sight towards HD 210121 passes through a high latitude cloud; that towards HD 147889 through a translucent cloud. The broad depression in the HD 210121 spectrum is the He I 3888 Å line that arises in the atmosphere of the star itself. Differences in relative CN and CH abundances in the two clouds are apparent from these spectra. The individual CN and CH lines are indicated, and for CN, lines arising out of* N = *0 and 1 are detected. In the HD 210121 cloud, the resulting CN excitation temperature* T_{ex} = *2,85 K is consistent with excitation in the 2.7 K cosmic background radiation field only. For the HD 147889 cloud,* $T_{ex} > 3$ *K is found, which suggests that local excitation effects play a role as well.*

Spectrometer (CES) on the ESO CAT telescope. One observational problem is that only few bright, early-type stars are available as background light sources at high latitudes. However, the improved sensitivity of the CCD detector, combined with the high spectral resolution ($\lambda/\Delta\lambda \approx 60{,}000$), makes the CES a uniquely qualified instrument to obtain high quality spectra towards less bright ($V \approx 8-9$ mag), somewhat later-type stars (latest we observed were late A-type). The suitability of the CES for atomic interstellar absorption line observations towards high latitude stars can be seen from the beautiful Na spectra presented by Andreani et al. in the previous issue of the *Messenger*.

The Southern high latitude clouds studied in this work were not taken from the Magnani et al. catalogue, but were chosen on the basis of IRAS 100 μm sky flux maps. Background stars were selected by comparison with the catalogue of stellar identifications (CSI). Eight different clouds with a total of about 40 background stars were selected for observations, which took place in July 1987 and 1988, and December 1987. Because little information is available on the reddening towards the stars, we first looked briefly at the interstellar Na D lines at 5890 Å to obtain an impression of the amount of interstellar matter in front of the stars. Stars which show strong, saturated interstellar Na lines in their spectra with equivalent widths W_λ larger than 100 mÅ clearly lie behind the cloud; stars with weak or no Na Lines lie in front of the cloud. If the distances to the stars are known from photometry, the Na line observations can also be used to place limits on the distances to the clouds (Hobbs et al. 1986; Andreani et al. 1988). Lines of interstellar CH, CH^+ and/or CN were sought towards about 25 stars which had strong interstellar Na absorption. More details of the observations and reduction can be found in de Vries and van Dishoeck (1988).

During our first two observing runs, one of us (CPdV) was present at La Silla; the third run in July 1988 was our first experience with remote observing from Garching. On the whole, we encountered only minor problems due to the fact that we were more than 10,000 km away from the telescope, although the observations were slightly less efficient, because it took a bit more time to point the telescope. We think remote observations are a good alternative for going to La Silla if the observation period is relatively short (a few nights). For longer periods however, remote observing was experienced to be far more exhausting than observing at La Silla because of the weird times you are busy, due to the 6 hours time difference with La Silla. However, we noticed one significant disadvantage in Garching compared with La Silla, namely the food service! Fortunately, *our* integration times were usually long enough to allow us sufficient time to go to Garching in the mornings to shop for our next meal . . .

CH

In the case of CH, we looked primarily for the $A^2\Delta$-$X^2\Pi$ (0,0) band at 4300.3 Å. Lines of interstellar CH with equivalent widths in excess of 1 mÅ were detected in the spectra of about 10 stars. The strongest CH line with $W_\lambda \approx 22$ mÅ was found for the line of sight towards HD 210121, a bright B5–6 V star ($V = 7.5$; $E(B-V) = 0.32$; $l = 56°.9$, $b = -44°.5$) which is fortuitously located behind the thickest part of a high latitude cloud. The CH measurements are of special importance, because the CH abundance has been found to be well correlated with the H_2 column density in interstellar clouds (Danks et al. 1984; Mattila 1986). They thus allow an independent determination of the H_2 column densities in high latitude clouds, a subject of considerable controversy. Estimates of H_2 column densities from integrated CO millimetre line intensities usually adopt conversion factors that have been calibrated from Giant Molecular Clouds in the Galaxy, and it is not clear a priori that these factors are also appropriate to high latitude clouds. For the cloud in front of HD 210121, four different methods for determining the H_2 content (CH abundance, CO millimetre emission, extinction, and IRAS 100 μm flux) have been compared by de Vries and van Dishoeck (1988). The various estimates suggest that most of the hydrogen is in molecular form in this cloud.

CH^+

Quite surprisingly, the CH^+ ion is not very abundant in high latitude clouds. The CH^+ $A^1\Pi$-$X^1\Sigma^+$ (0,0) line at 4232.5 Å was detected ($W_\lambda > 1$ mÅ) towards only 3 of the 10 stars observed. These observations are interesting because CH^+ is thought to be formed only in shock-heated gas. The fact that the CH^+ abundance is comparatively low suggests that shocks do not play a dominant role in the chemistry in the cloud. This is in contrast with the conclusion of Magnani, Blitz and Wouterloot (1988), who had conjectured that shocks might be important based on large OH and H_2CO abundances found from radio measurements.

CN

During our most recent observing run in July 1988, we also searched for lines of CN in the violet $B^2\Sigma^+$-$X^2\Sigma^+$ system around 3875 Å, where the response of the CCD detector is still good. Strong interstellar lines were detected in the spectra of 4 of the 5 observed stars. Figure 1 shows the observed spectrum towards HD 210121. As a bonus, the spectrum also includes lines of the nearby CH $B^2\Sigma^-$-$X^2\Pi$ (0,0) system around 3890 Å. Although these CH lines are intrinsically weaker than the A-X 4300.3 Å line, they provide an independent check on the inferred column density.

The strongest CN line is the $R(0)$ line, which has an equivalent width of about 25 mÅ towards HD 210121. Unfortunately, this line is strongly saturated, so that the determination of column densities requires some assumption about the velocity spread parameter b in the cloud. One method to obtain an estimate of b is to compare the strengths of the $R(1)$ and $P(1)$ lines, which are also clearly visible in the spectrum. These lines originate in the same lower level $N = 1$ of the molecule, and should therefore give the same column density. For HD 210121, the $R(1)$ and $P(1)$ data are in harmony for $b \approx 1$ km s^{-1}, a value that is consistent with the width of the CO millimetre line towards the star (Knapp et al. 1988). A more powerful method for constraining both the CN column density and the value of b is to compare the CN violet system results with measurements of CN in the red $A^2\Pi$-$X^2\Sigma^+$ (2,0) system around 7900 Å (cf. van Dishoeck and Black 1988*a*; see also the *Messenger* **38,** 16). Searches for the CN red system towards HD 210121 revealed no interstellar lines with $W_\lambda >$ 2 mÅ. This negative result immediately provides an upper limit on the CN column density in the lower $N = 0$ level of 10^{13} cm^{-2}, and suggests that b cannot be smaller than 1 km s^{-1}. Thus also information on the "turbulence" in high latitude clouds can be obtained from these observations, which may provide further insight into their origin.

Once the column density in $N = 0$ is well constrained, the remaining CN data can be used to determine the excitation of the molecule. The observed relative populations in the $N = 0$ and $N = 1$ levels can be characterized by an excitation temperature T_{ex} (1–0) = (2.85 ± 0.25) K. The upper limits on lines out of $N = 2$ result in T_{ex} (2–1) ≤ 4.7 K. Thus the CN excitation in the HD 210121 cloud is controlled by the 2.7 K cosmic background radiation, and local effects play a negligible role. This conclusion, in turn, provides limits on the electron density in the cloud.

TABLE 1. *Comparison of the HD 210121 cloud with other clouds*

Species	HD 210121	ζ Oph	HD 169454	HD 147889
H_2	(0.6–1.0)(21)	4.2(20)	(1–2)(21)	> 2(21)
H	(1–5)(20)	5.2(20)	≥ 9(19)	—
CH	3.5(13)	2.5(13)	4.6(13)	8.0(13)
CH^+	6.0(12)	2.9(13)	—	3.0(13)
CN	1.4(13)	2.9(12)	5.5(13)	1.5(13)
CO	(0.5–1.5)(16)	2.0(15)	(1–9)(16)	> 1(16)
A_v (mag)	1.0	0.9	3.5	~ 4

Note: The table lists column densities in cm^{-2}. The notation a(b) indicates $a \times 10^b$.

Comparison With Other Clouds

How do the CH, CH^+ and CN results for the high latitude clouds compare with those for classical diffuse and dark clouds? Table 1 lists the observed column densities for the HD 210121 cloud together with those for the ζ Oph diffuse cloud. Table 1 also includes the results for two thicker, so-called translucent clouds with visual extinctions of about 3 mag (van Dishoeck and Black 1988*a*). The observed spectrum of the translucent cloud in front of HD 147889 around 3880 Å is reproduced in Figure 1 as well. From this figure, it is clear that the relative abundances of CN and CH differ greatly in the two clouds: the CN lines are about equally strong in the two spectra, but CH is clearly relatively much stronger towards HD 147889 than towards HD 210121. From Table 1, it appears that the CH column density is only slightly larger in the HD 210121 cloud compared with the ζ Oph cloud, whereas the CH^+ column density is even smaller. On the other hand, both CN and CO are more abundant in the high latitude cloud, although their column densities are not yet as large as those found in translucent clouds.

Detailed steady-state models are currently being developed to interpret these findings (van Dishoeck and Black 1988*a, b*). Initial results suggest that the large CO and CN abundances most likely result from the fact that the high latitude clouds are exposed to less intense ultraviolet radiation than clouds in the galactic plane. The relatively low CH abundance is most easily explained if carbon is more depleted onto grains in high latitude clouds compared with diffuse clouds. Finally, as mentioned before, the small amount of CH^+ suggests that shock processes play a less important role in the chemistry of high latitude clouds compared with diffuse or translucent clouds.

In our future absorption line observations, we intend to investigate whether gradients occur in relative abundances across a cloud in cases where we have identified several background stars. Also, we intend to search for millimetre emission of several other molecules to test the chemistry further and to constrain the physical conditions. In summary, a considerable amount of information on the origin and the physical and chemical state of these interesting high latitude clouds can be obtained from combined optical and millimetre observations.

References

Andreani, P., Ferlet, R., Lallement, R., and Vidal-Madjar, A. 1988, *The Messenger*, **52,** 47.

Blitz, L. 1988, in "Structure of Galaxies", Proc. 10th European Regional Meeting of the IAU, ed. J. Palous (Czech Academy of Sciences, Prague), p. 204.
Danks, A.C., Federman, S.R. and Lambert, D.L. 1984, *Astron. Astrophys.* **130,** 62.
Désert, F.X., Bazell, D., and Boulanger, F. 1988, preprint.
de Vries, C.P. and Le Poole, R. 1985, *Astron. Astrophys.*, **145,** L7.
de Vries, C.P. and van Dishoeck, E.F. 1988, *Astron. Astrophys.*, in press; and in preparation.
Hobbs, L.M., Blitz, L., and Magnani, L. 1986, *Astrophys. J. (Letters)*, **306,** L109.
Knapp, G.R., Drdla, K., and van Dishoeck, E.F. 1988, in preparation.
Magnani, L., Blitz, L., and Mundy, L. 1985, *Astrophys. J.*, **295,** 402.
Magnani, L., Blitz, L., and Wouterloot, J.G.A. 1988, *Astrophys. J.*, **326,** 909.
Mattila, K. 1986, *Astron. Astrophys.*, **160,** 157.
van Dishoeck, E.F. and Black, J.H. 1988*a*, *Astrophys. J.*, submitted.
van Dishoeck, E.F. and Black, J.H. 1988*b*, in *Rate Coefficients in Astrochemistry*, eds. T.J. Millar and D.A. Williams (Kluwer, Dordrecht), in press.

Evolutionary Features in Distant Clusters of Galaxies

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1. Introduction

The study of distant clusters of galaxies is fascinating and fundamental for a variety of astrophysical problems ranging from the understanding of the evolution of the galaxies as a function of the cosmic time to the comprehension of the large scale structure of the Universe. Relevant contributions on this topic occurred in the recent years, following the pioneering work of Gunn and collaborators (Gunn, Hoessel and Oke, 1986) in the detection of clusters at high redshift, of Butcher and Oemler (1984) in emphasizing possible evolutionary effects present in distant galaxies and of Tinsley (1977) with her theoretical work.

No matter what our goals are, in observational cosmology we are always faced with the problem of using galaxies as tracers of the geometry of space, measuring their position in the sky and estimating their luminosity and distance. This is a relatively simple task if we refer to the nearby region of space, say, at cosmological distances smaller than z = 0.2. Here galaxies are still relatively bright and extended objects and they can be recognized and easily separated from stars. However, as soon as we look deeper in space, attempting to study galaxies located farther away, we start dealing with almost unresolved faint objects and it becomes difficult both to measure redshifts and estimate uncontaminated counts as a function of the magnitude (Fig. 1).

A way around the problem may be to use a combined approach by means of a multicolour photometry (Loh and Spillar, 1986, Rakos, Fiala and Schombert, 1988) properly matched with a set of evolutionary photometric models of galaxies. With this in mind, we started some time ago with a long term project on distant clusters. In this paper we present some of the preliminary results we have obtained; the observations have been carried out at La Silla and the analysis in Milano where, with the help of the ESO staff, we have installed the needed software for the data reduction.

2. Observations

We observed two high redshift clusters taken from the survey published by Gunn, Hoessel and Oke (1986): 2158 + 0351 at a nominal redshift of z = 0.445 and 0020 + 0407 at z = 0.689. The redshifts were taken at their face value and should eventually be confirmed.

A set of CCD frames were collected during two observational runs at the Cassegrain focus of the ESO 3.6-m telescope in November 1986 and November 1987. We used the three-colour Gunn photometric system (Thuan and Gunn, 1976, Wade et al. 1979) and the EFOSC focal reducer.

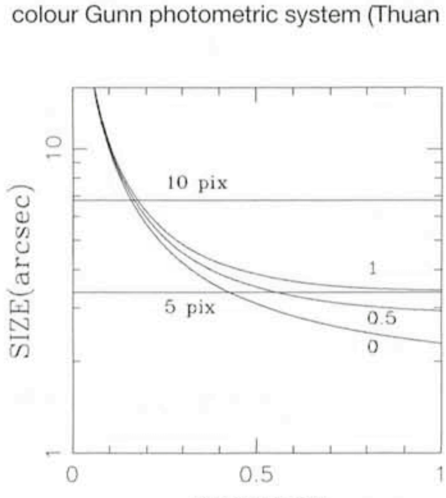

Figure 1: *The apparent size of the galaxies versus redshift. A galaxy size of 25 Kpc and a Hubble constant H_o = 50 are assumed. Each curve is labelled with the value of the deceleration parameter q_o. As a reference also the linear dimensions on our CCD frames are reported (the scale is 0.675 arcsec/pixel).*

The images were reduced using the MIDAS package (see Users Guide, Image Processing Group ESO V 4.3) installed in the reduction facilities of the Observatory of Brera while the detection of the objects in each frame and their photometric measurements have been carried out using the INVENTORY software (West and Kruszewski, 1981) implemented in MIDAS. We are confident that our completeness is down to the magnitude r = 23.5 as it is apparent from a direct inspection of the features detected automatically in the CCD images. The uncertainty in the photometry of the faintest objects detected should be less than ± 0.3 magnitudes (for details see Molinari, 1988).

The two clusters are shown in Figures 2 and 3. These images have been obtained by adding the CCD frames at our disposal in the r band and are equivalent to an integration time of 50 minutes for 2158 + 0351 and 85 minutes for 0020 + 0407. In Figure 4 we have marked all the objects photometered in 2158 + 0351 just as an example of the completeness attained. No serious attempt has been pursued to discriminate between stars and galaxies using the analysis of the photometric gradient of the single features. This is because at such redshifts the galaxies are expected to be essentially seeing limited images and cover only a few pixels on the CCD frame. As shown also in Figure 5, the brightest members of 2158 + 0351 are 8 × 8 pixels wide and obviously the situation gets worse for the more distant cluster. It is because of this and the difficulty to always have subarcsec seeing that we decided to use a statistical approach to the photometric information available (magnitudes and colours).