QUASI STELLAR OBJECTS AND ACTIVE GALACTIC NUCLEI

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1. INTRODUCTION

The role of the Schmidt telescopes in the discovery of the Quasi Stellar Objects and of the Active Galactic Nuclei, and in the understanding of their properties was and continues to be of the greatest importance. Thousands of Radio-Sources have been quickly associated to their optical counterparts thanks to the worldwide availability of the Palomar Observatory Sky Survey plates and charts and more recently of the films of the ESO B Survey. Other thousands of QSOs and AGNs devoid of radio emission are found by the large Schmidts nowaday in operation. This wealth of data give fundamental cosmological knowledge and insight in the physical processes occuring in these objects. I'll concentrate in this Review on two specific topics, namely on the discovery techniques and on the study of the optical variability. To both subjects, the 67/92 cm Schmidt telescope here at Asiago has made significant contributions. The first topic is treated in several excellent papers, such as the one by M. Smith (1978) and the one by P. Veron (1983); the material presented in the second part is largely new. In the following, I'll use rather loosely the terms QSOs and AGNs to designate a variety of objects including Quasars (those QSOs in catalogs of Radio-Sources), high-redshift compact galaxies with emission lines, BL LACs et similia.

2. DISCOVERY OF QSOs WITH SCHMIDT TELESCOPES

Almost immediately after the identification of the first quasars, Schmidt telescopes, and in particular the 48-inch at Mount Palomar, were put to work to ascertain the existence of objects having the same optical features but devoid of strong radio emission. The technique then used was the one devised in the pioneering surveys of blue stars in high galactic latitudes carried out at Tonantzintla Observatory: two or three exposures are successively taken on the same plate, after a filter change and a small displacement of the telescope. An example is given in Fig. 1, taken from an Asiago plate; a UV quasar, 4C 49.22, is easily seen. This plate employes a most used combination constituted by the E-K 103a-O emulsion plus the U and B filters. The exposure times are so calibrated to produce approximately equal images for an A0 star. As is well known, QSOs occupy a large area of the (U-B, B-V) plane were no main sequence

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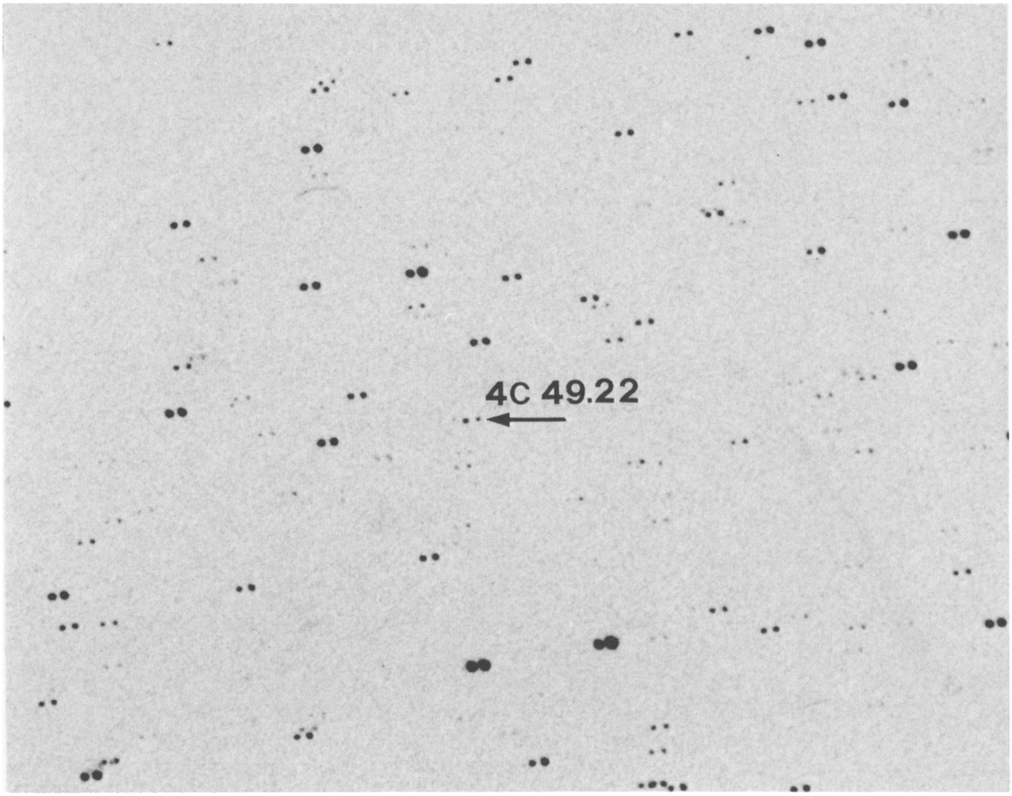
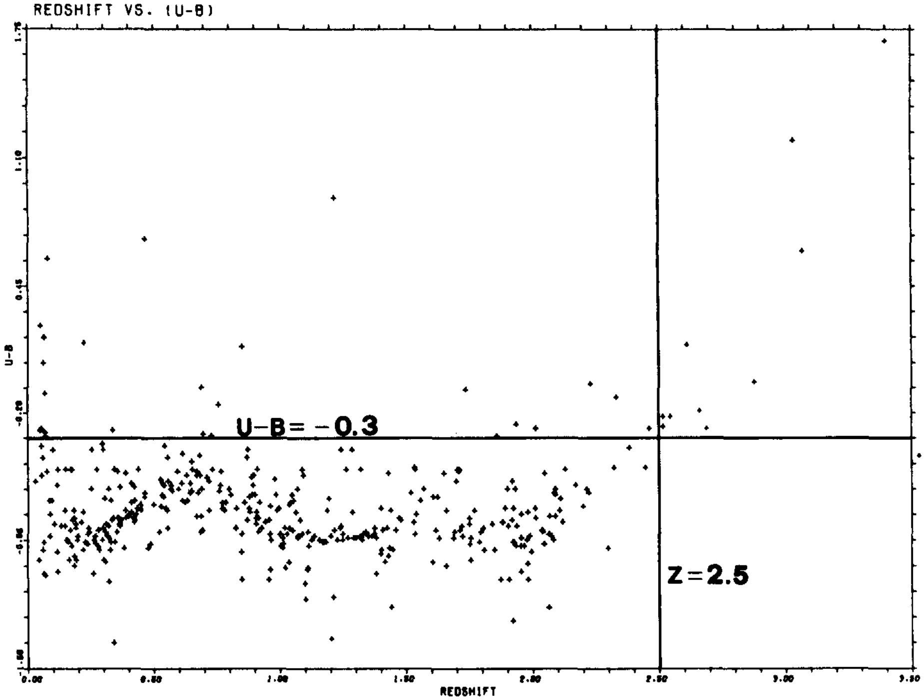


Figure 1 - A two-colour image of the Quasar 4C 49.22, from an Asiago plate of the still unpublished field around χ U Ma.

stars are found; see Fig. 2, taken from the Asiago Catalogue of QSOs, ed. 1982. With few exceptions, all objects with $z < 2.5$ have $U-B < -0.3$; therefore, if the search is limited to objects bluer than this limit, then one does not introduce systematic biases against particular z values. The situation is less clear for higher z, because reliable UBV data are lacking. At any rate, from Fig. 2 and also from theoretical considerations, redder colors are expected, so that the discovery of QSOs with $z > 2.5$ using this multicolour technique seems virtually impossible. Going back to QSOs with $z < 2.5$, we see a first limitation of the method, namely that from the colors one can obtain at most a rough estimate of their redshifts. The reason for the trend of the colors with z is qualitatively understood: the non-thermal shape of the continuum and the motion with z of the bright emission lines across the fixed color bands produce a typical pattern shown in Fig. 3 (Sandage, 1967). The estimate of z from the colors however is so uncertain to be practically useless even for statistical discussion of limited scope. A second drawback of the multicolour method is the fact that too many spurious candidates are also found, especially at $B < 18.5$ (see Veron, 1983). It becomes then imperative to supplement the $U-B <-0.3$ criterium with additional constraints. For in-



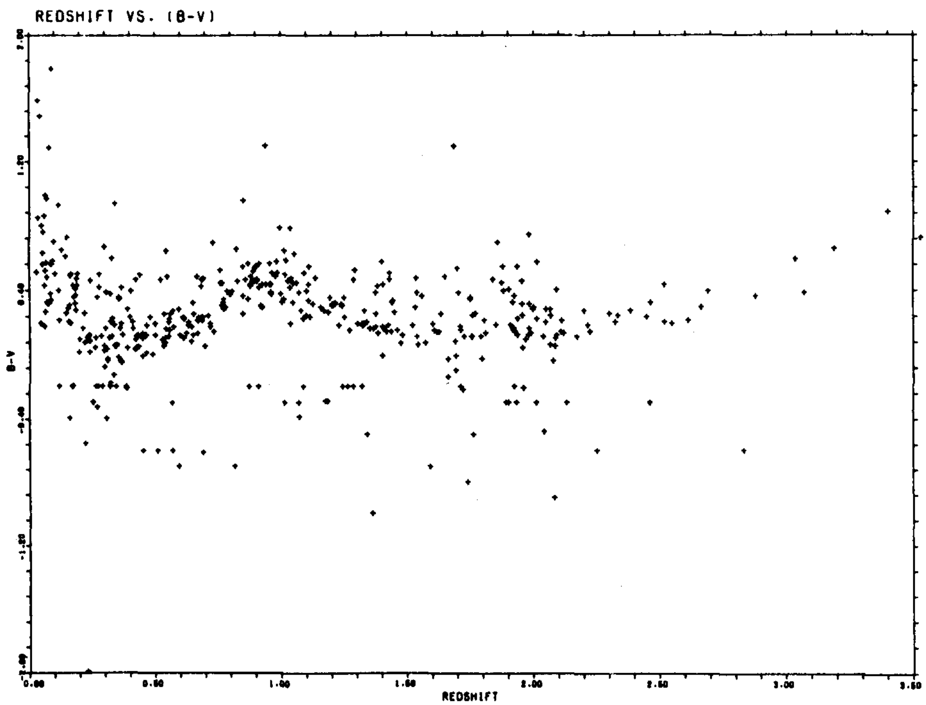


Figure 2 - The U-B, B-V colours of the QSOs in the Asiago catalogue. Very few objects have U-B>-0.4, unless z>2.5.

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stance, Braccesi (1967) remarked that the non thermal continuum renders the QSOs brighter in the near-IR than normal stars with the same U-B. Results for the field 13h, +36d have been published by Braccesi et al. (1970). Unfortunately the low efficiency of the near-IR emulsions prevented a large scale application of the method; a recent survey using the IR criterium has been carried out by Kron and Chiu (1981).

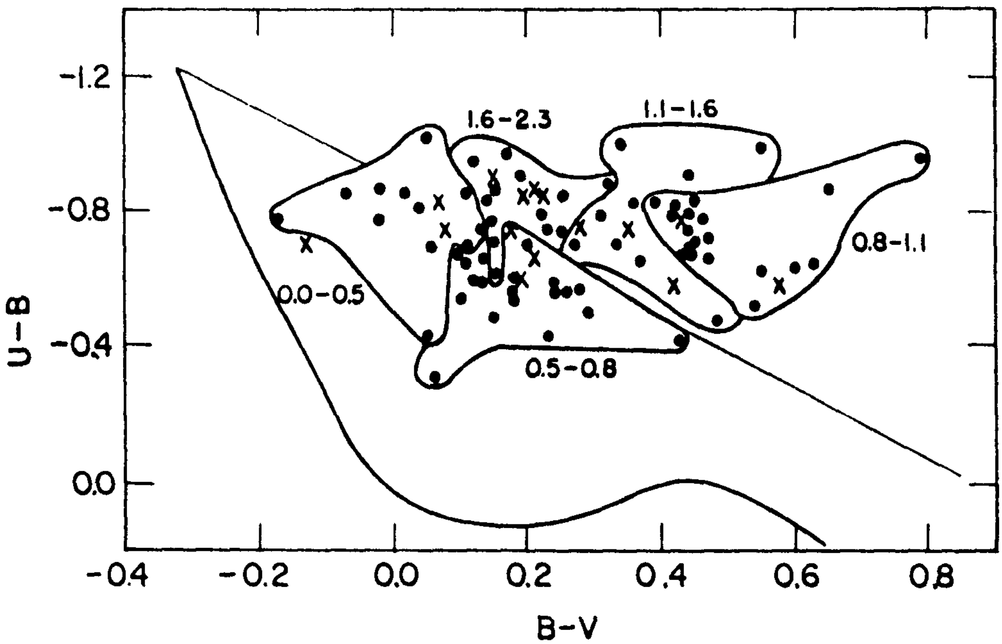

Figure 3 - The (U-B, B-V) locus of QSOs as function of z. The correlation of colors with redshift is not precise enough to permit statistical discussions or unequivocal identifications.

A second useful restriction has been the requirement of zero proper-motion. This precaution was introduced by Sandage and Luyten (1967) and has been used more recently in the already mentioned survey by Kron and Chiu (1981). Once again, the very existence of the first epoch POSS plates has been of the greatest value. Finally, the optical variability is of great help to discriminate bone-fide QSOs from blue stars (Usher et al., 1983). Despite all ingenuity however, the multicolour metod requires subsequent spectroscopy with a large telescope, in order to determine the nature of the candidate and measure its redshift.

I have collected in Table 1 some surveys done with this multicolour technique. Although completeness is not claimed, the Table gives a fair idea of the great amount of research thus done. The Asiago Catalogue of QSOs, essentially complete to the end of 1981, contains some 150 objects thus discovered. Let me add a few words about the Asiago Survey. The plates were obtained between 1967 and 1971; three fields were published but

TABLE 1 - MULTICOLOR SURVEYS OF QSOs AND AGNs WITH SCHMIDT TELESCOPES

Designation and Main References	Schmidt Telescope and Combination
PHL: Haro and Luyten (1962) Sandage and Luyten (1967,1969)	Palomar 48 inch 103a-D + UBV, zero proper motion
Sandage and Veron (1965)	Palomar 48 inch 103a-O + UB
Rubin et al. (1967)	Palomar 48 inch 103a-D + UBV
BFG; Braccesi, Formiggini and Gandolfi (1970)	Palomar 48 inch 103a-O + UB; 103a-D + V; I-N (sens.) + I
W; Weistrop (1972)	Palomar 48 inch 103a-O + UB; 103a-D + V
PG; Green (1976)	Palomar 18 inch IIa-O (sens.) + UB
Berger and Fringant (1976)	Palomar 48 inch 103a-D + UBV
Steppe (1978)	Palomar 49 inch 103a-E + R; 103a-O + UG
Usher (1981)	Palomar 48 inch 103a-D + UBV
Arp and Surdey (1982)	Palomar 48 inch 103a-O + UB
Iriarte and Chavira (1957)	Tonantzintla 26/30 inch 103a-D + UBV
Richter and Sahakjan (1965)	Tautenburg 400/200/134 cm 103a-O + UB; 103a-G + V
A; Barbieri et al. (1968)	Asiago 92/67 cm 103a-O + UB
Naguchi et al. (1980)	Kiso 105 cm 103a-E (sens.) + UGR

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the lack of adequate spectroscopic facilities prevented for long time the proper identification of their content. But now, thanks to the generous efforts of Laura Erculiani-Abati, data are finally coming; supplementing the Asiago plates with material taken at the Tautenburg and UK Schmidts and with slit spectra at the 6 m telescope in Zelenchuskaya she has already confirmed more than a dozen QSOs. These first encouraging results are found in her paper at this Conference and will prove useful to determine the areal density of the brighter objects.

I move now to a second, extremely successful technique to utilize the Schmidt telescope to discover QSOs and AGNs, namely with low dispersion objective prisms. With them, low redshift excited galaxian nuclei and emission line regions are easily found, as was proved in the classic works of Markarian (1967). At much higher redshifts, the bright line Ly-alpha enters the blue and visible regions, so that QSOs with $1.7 < z < 2.4$ are mostly found, with a non negligeable number having redshifts as low as 1.6 or as high as 3.4. An example is given in Fig. 4,

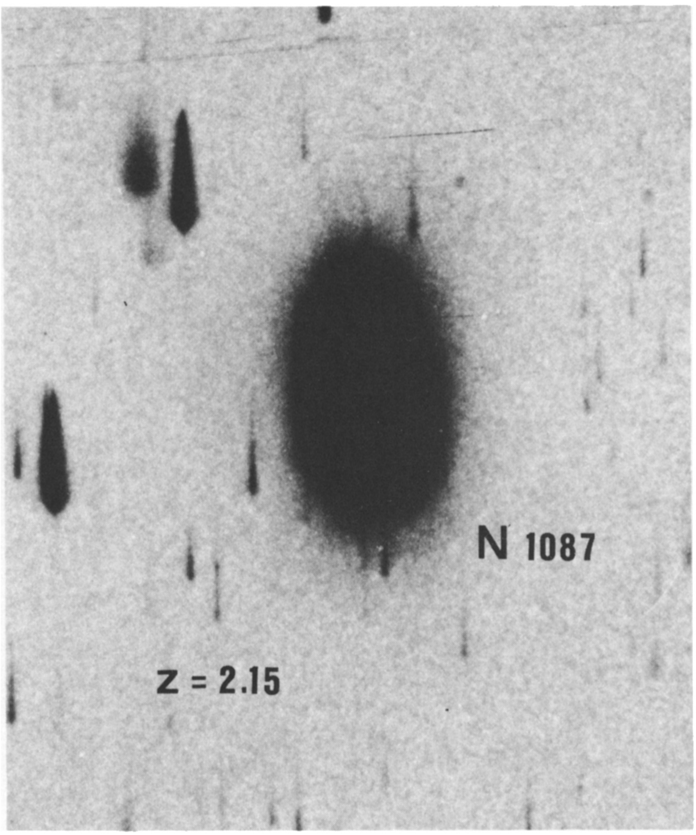

Figure 4 - A radio-quiet QSO found a UK Schmidt plate, in the still unpublished survey of the field at 2h +0d.

from a survey we have in progress with the UK Schmidt in a field at 2h 0deg. The advantages of the objective prism technique are easily understood; the efficiency is so terribly high that hundreds of new QSOs are added to the Catalogues every few months. Indeed the yield of a single UK Schmidt plate is between 100 to 200 candidates (Smith, 1978), for most of which a fair estimate of the redshift is immediately available. Again without any claim of completeness, I have listed in Table 2 some surveys done with objective prisms.

TABLE 2 - OBJECTIVE PRISM SURVEYS OF QSOs AND AGNs WITH SCHMIDT TELESCOPES.

Designation and Main References	Schmidt Telescope,Plate and Dispersion
Markarian (1967)	Byurakan 102/132 cm IIa-F 2500 A/mm at H beta
CTIO; Osmer and Smith (1980) UM; MacAlpine et al. (1977) Smith (1975)	CTIO 61/91 cm IIIa-J (sens.) 1740 A/mm at H beta
Savage and Bolton (1979)	UK 48 inch IIIa-J 2480 A/mm at H gamma IIIa-J + UB
Hazard, Arp and Morton (1979) Arp and Hazard (1980)	UK 48 inch IIIa-J 2480 A/mm at H gamma
Weedman (1983)	Burrel 61/91 cm IIIa-J

As is well know, these surveys have been supplemented with GRISM searches at larger telescopes, so that the technique is often collectively called SLITLESS SPECTROSCOPY (see for instance Osmer, 1980). It is of interest now to ask what the colors are of these objective-prism QSOs: it turns out that most of them are also blue, as expected. It has become good practice now, especially at the UK Schmidt, to obtain both U and B and objective prism plates. Modernization of the Blink machines with TV display following the ideas of J. Bolton (Savage, 1978) is of great help in the examination and intercomparison of the plates. Veron (1983) gives a good discussion of the completeness of the several surveys, variously estimated between 50 and 80%. Here, I add few practical considerations. As already remarked, objective prisms discover QSOs mostly in the range $1.7 < z < 2.4$. The effect of this observational selection is clearly seen in Fig. 5, built using the successive editions of the Asiago Catalogue: in 1966 the Catalog consisted entirely of Quasars, mostly from the 3CR Catalog. One year later, several "interlopers" or Blue Stellar Objects, as they were named at that time, were added and produced a pronounced peak around $z = 2.0$. In 1975 the identification of radiosources from several catalogs (4C, PKS, CT, Ohio etc.) had been very succes

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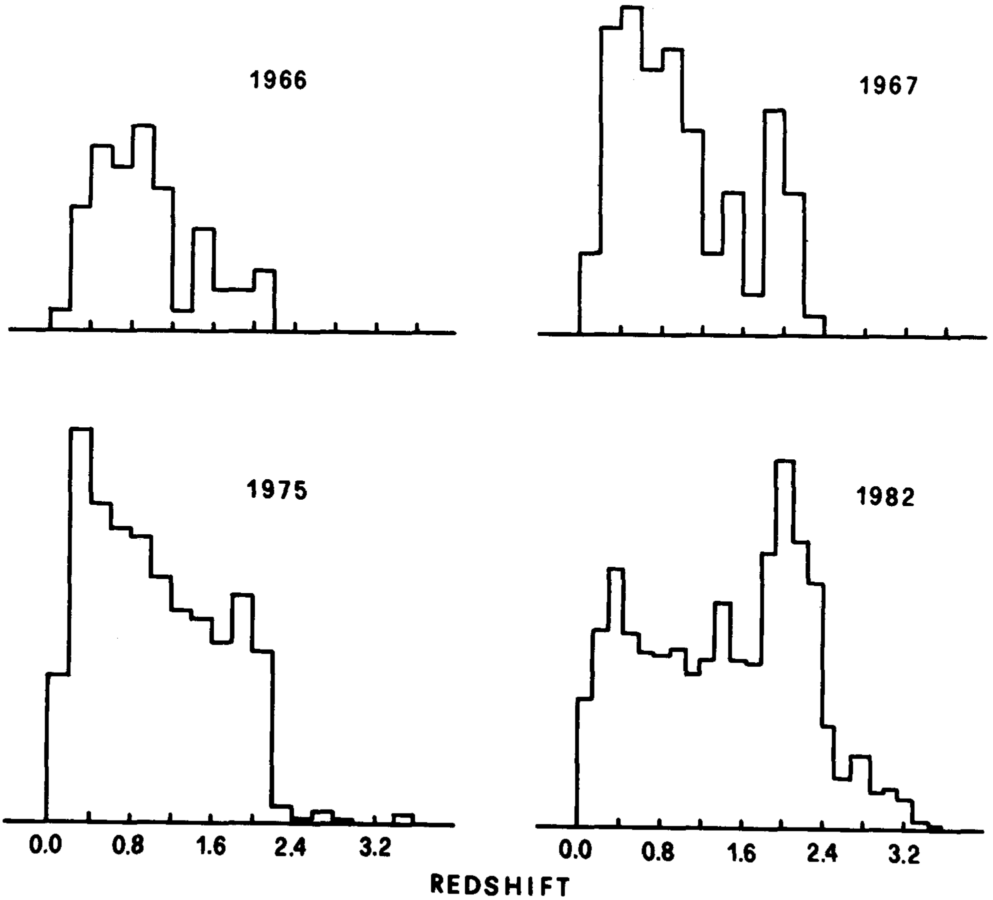

Figure 5 - The distribution of the redshifts in the successive editions of the Asiago Catalog of QSOs.

sfull, and that peak largely reduced. Taday, it dominates entirely the distribution. This observational bias against intermediate redshift could be overcome by a mediumsized Schmidt telescope in Space, capable to investigate in the near UV large fields with an objective prism. Therefore the discovery of intermediate redshift QSOs is at least in principle possible from Space. More difficult is the situation for very high z's, even assuming that those objects do indeed exist. Even the Space Telescope will be of limited help in their discovery, because its field is so limited. Hopefully one will soon discover efficient ways to utilize Schmidts on the ground for this extremely important project. To conclude this Section, it is worth recalling that objective prisms discover QSOs that on average seem one to two magnitudes fainter than quasars. However, great care is needed to discuss this difference; the truth is that the vast majority of QSOs lack good magnitudes. The variability only adds to this unsatisfactory situation.

3. OPTICAL VARIABILITY OF QSOs AND AGNs

In this Section I'll present material mostly obtained with the larger of the two Asiago Schmidts. Indeed, taking advantage of the great collection of plates of the Supernovae Search and of other long-term programs, we have been able to study the variability of QSOs over a period of almost two decades. Occasionaly, films from the smaller Schmidt proved of help, although the short focal length prevents good magnitude estimates. References to the papers published so far can be found in Barbieri et al. (1983). In total we have examined some 2000 plates, investigating both stellar and compact or slightly diffuse objects.

Because most of the material was already available for other programs, the Asiago sample gives a fair idea of the behaviour of the "average" QSO in respect of the optical variability. The largest selection factor is the brightness, due to the limiting magnitude of the plates, around the 19th. Through it however more insidious selection effects can be introduced in the sample, for instance because Quasars tend to be brighter than radio quiet objects, as already remarked in Sect. 2. The magnitudes are usually estimated by eye in respect to surrounding stars. Although this method is perhaps not extremely precise, it has in our opinion a great advantage, namely the possibility to refer the variable at the same time to a fair number of stars. Spurious variations are then easily found, and that is the most critical phase in the entire study. It is difficult in fact to study the variability of QSOs and AGNs, because of their morphology and of their peculiar colors. In the literature there are indeed several cases of spurious variations, especially on photographs taken with short focal length telescopes (e.g. Kinman, 1969). I give two examples to illustrate this point. The first is represented by the anonimous galaxy at 8h+48deg, discovered by G. Romano as a twelwth mag variable "star" (see fig. 6). The galaxy is diffuse, without a bright nucleus, with a complex structure extending several arcsecs. Although we cannot exclude genuine variability, most of the variations, never exceeding 0.6 mag, must be attributed to different conditions of sky transparency, seeing, plate quality etc. On the other hand, we have more than 100 plates of 3C 48, a well known compact galaxy with a much stronger concentration of the light in a stellar nucleus. In this case the variations are contained within 0.4 mag and we would consider it a variable QSO if not for the photoelectric data by Matthews and Sandage (1963). The Asiago material possesses therefore a good internal consistency and is examined with a cautious eye. Our experience is that a precision of ± 0.15 mag is expected on the average plate, and we disregard variations smaller than 0.3 mag. It is perhaps for this conservative attitude that the Asiago Survey doesn't find such a high number of variable QSOs as other surveys do.

Furthermore, as a consequence of the lack of control on the dates of most of the data points, we content ourselves with a very simple statistical

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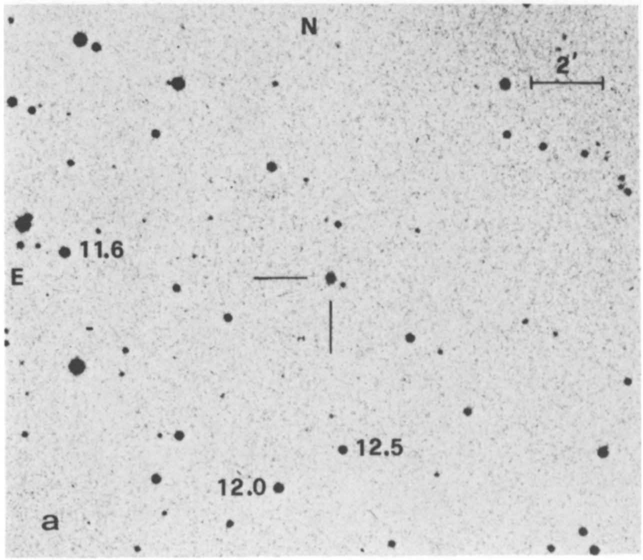

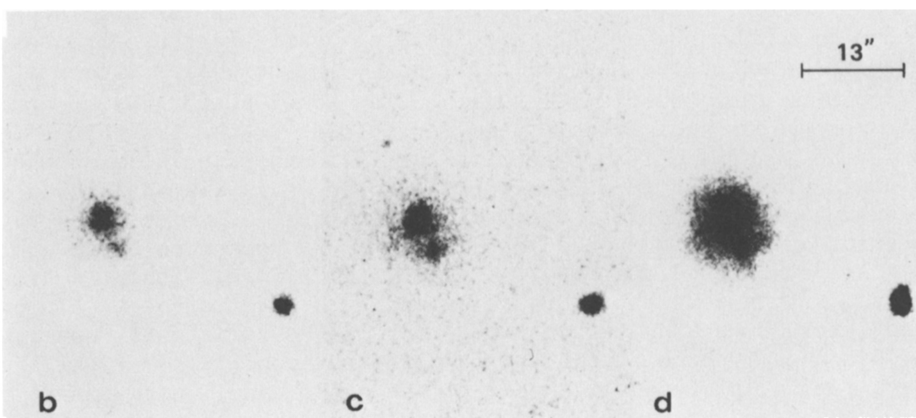

Figure 6 - The anonimous compact galaxy at 8h + 48° discovered as a 12th mag variable "star" on Asiago Schmidt plates. At the bottom, the images of the galaxy obtained with the 182 cm telescope at Cima Ekar (Barbieri et al., 1982)

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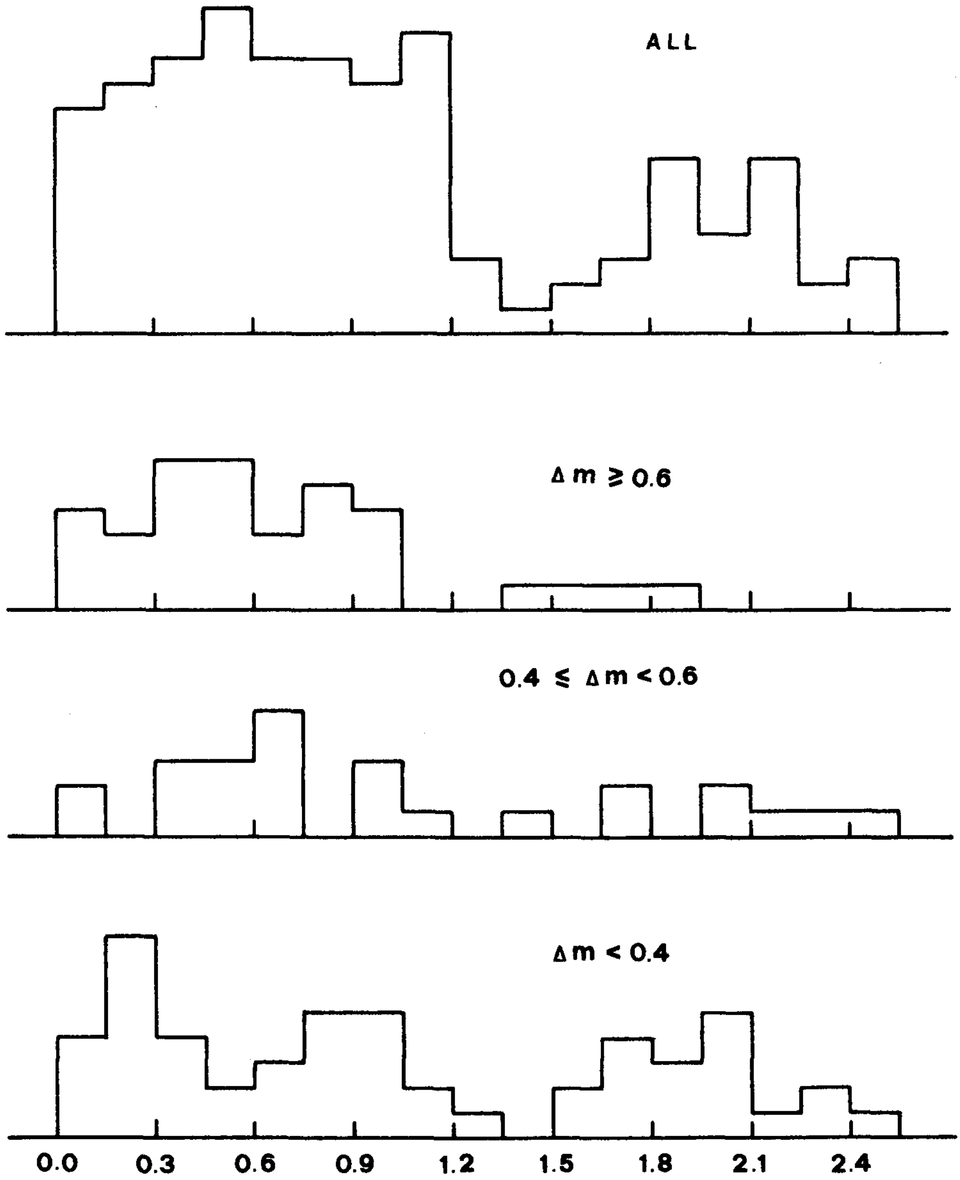

Figure 7 - The Redshift distribution of the Asiago sample. Only one large amplitude variable is found at z>1.8. BL Lac objects are excluded from this figure.

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parameter, namely the maximum amplitude DB=Bmin - Bmax observed on the available material.

Let's now examine some results. Firstly, 7 out of 8 BL Lac objects in the sample have been found highly variable. This high percentage clearly separates this sub-class of AGNs from the other QSOs. For those objects with emission-line spectra, Fig. 7 presents the redshift distribution. If we divide the sample in two classes, one with DB <= 0.5 and one with DB >= 0.6 then an intriguing difference is found: there is only one large amplitude variable at z > 1.8, against several non variable objects This paucity of high redshift variables cannot be due, at least not entirely, to the shortening of the proper time in the rest frame of the QSO: this is shown in Fig. 8 where we have the time coverage for the two classes. Several non variable QSOs have been densely observed in their time frame for almost a decade. Variations like the ones experienced by

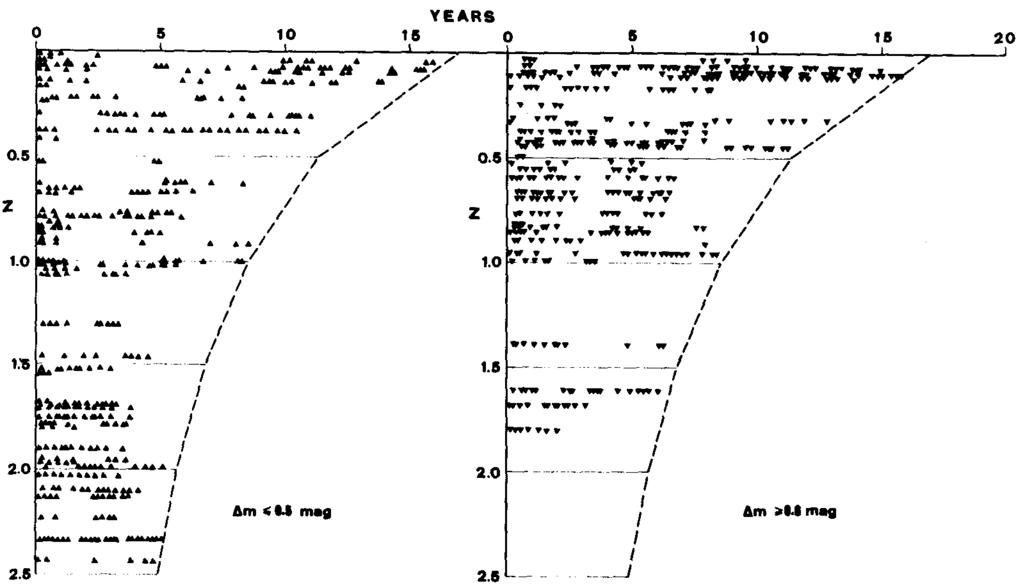

Figure 8 - The coverage in proper-time of highly variable and non variable QSOs in the Asiago sample (BL Lac objects are excluded from this figure).

3C 345 or 3C 446 would not have escaped detection. To a greater extent, the apparent magnitude can be the cause of this effect, because higher redshift objects tend to be fainter (in our sample), with a consequent deterioration of the data. Our conservative attitude raises in this case the detection treshold for genuine variations and we may disregard as plate fluctuations true brightness changes. A case in point is PKS 1116 + 12; it is a 19th mag QSO at z = 2.112 at the plate limit. It has

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been observed also in the Rosemary Hill Observatory Survey (Pica et al., 1980), and they find an amplitude of more than one mag. But the QSO must be at their very limit too, and we cannot consider it as truly variable. Even taking into account those two effects, a genuine physical property of the high-redshift QSOs cannot be excluded at this moment. Few more years of observations will undoubtely clear this important point. Going back to Fig. 8,a closer inspection would reveal that the high amplitude variables have been on the average more densely observed than the others: taking that into account we conclude that some 15% of QSOs are truly non variable over a period of 5 to 20 years, while at least 50% do change luminosity by 2 to 30 times. With the exception of the already discussed possible correlation with z, the rate of variability does not depend, at least not strongly, on other properties of the objects like radioemission; even radiovariability is not hundred percent correlated with the optical one.
We have in progress a careful analysis of the Asiago data, but this is not the place to present the full results. It is appropriate however in this Colloquium to point out the great amount of work done with our Schmidt and to wish many more years of fruitful researches.

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