THE MAGELLANIC CLOUDS

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ABSTRACT

Contributions to our present knowledge of the Magellanic Clouds based on observations with Schmidt telescopes are discussed.

1. INTRODUCTION

During a long period almost all the research on the Magellanic Clouds was carried out with the aid of material gathered at the Boyden Station of the Harvard Observatory, first at Arequipa, Peru (1889-1927) and then at Bloemfontein, South Africa. From 1914 on Lick Observatory contributed by measurements of radial velocities at its station in Chile. In the early 1950:s several new telescopes, including radio telescopes, were in operation in Australia, South Africa, and South America. A new epoch for astronomical observations in the southern hemisphere was beginning.

In 1932 the optical system of the "Schmidt camera" had been described (Schmidt 1932), and during the next three decades a number of Schmidt telescopes were built. In the early 1960:s 19 were ready or expected to be in use soon (apertures over 50 cm; see *Telescopes, Stars and Stellar Systems* vol. 1, p. 239, 1962). Of these, only two were located sufficiently far south to serve for Magellanic Clouds research; the ADH telescope at Boyden Station (lat.-29°) and the Schmidt telescope at Uppsala Southern Station, Mt Stromlo Observatory (-35°). At Mt Stromlo Observatory was also a 20 cm Meinel-Pearson Schmidt camera in use.

During the following two decades Schmidt telescopes were constructed for use in the south, or moved there for continuous or temporary research. Table 1 lists the southern Schmidt telescopes. It includes a reference to the Schmidt camera briefly used on the lunar surface for observations of the Clouds - lack of space makes it impossible to discuss its important contributions here (see Page, Carruthers, 1978, 1981). In a review that mainly deals with surveys we must, however, also consider other widefield telescopes with which important work on the Clouds have been carried out during the last three decades (Table 2).

M. Capaccioli (ed.), Astronomy with Schmidt-Type Telescopes, 333–346.

Table 1. Schmidt telescopes used for research on the Clouds.

Telescope	Observatory	Dimensions/Scale	Prisms	In use
ADH	Boyden Station South Africa	81/90/303 cm 68"/mm	240 Å/mm at Hγ	1950-74
Uppsala Southern Schmidt	Uppsala Southern Station, Mt Stromlo, Australia	50/65/175 120	480	1956-
Meinel-Pearson	Mt Stromlo Observatory, Australia	20/26/20 1000		1958-
Hamburg-Schmidt	Boyden Station, South Africa	36/42/63 330	710	1967-
Curtis-Schmidt	Cerro Tololo Inter-American Observatory, Chile	61/91/214 97	580 1360	1967-
ESO Schmidt	European Southern Observatory, La Silla, Chile	100/162/306 67.5	450	1972-
SRC Schmidt	UKST, Siding Spring Observatory, Australia	122/183/307 67.5	2400 800 108	1973-
Far Ultraviolet	Naval Research Laboratory, Lunar surface (Apollo 16)	See Carruthers, G.R.: 1973, Appl.Optics 12, 2501		1972,21-23/4

Note: Uppsala Southern Schmidt was moved to Siding Spring Observatory in October, 1981.

Table 2. Other wide-field telescopes used for surveys of the Clouds.

Telescope	Observatory	Dimensions/Scale	Prisms	In use
MtWilson 10" camera	Lamont-Hussey Observatory, Bloemfontein, South Africa	25 cm 159"/mm	300 Å/mm at 5890 Å	1950
GPO Astrograph	Zeekoegat, South Africa La Silla, Chile	40 51.5	110 Å/mm at 4210 Å	1961-66 1968-

Note: A twin 7-inch f/2.5 Ektar camera was used by de Vaucouleurs (1954) at Mt Stromlo Observatory.

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Recently the new large southern reflectors have been used for a variety of surveys, of the sampling kind, of the Magellanic Clouds, in particular with the powerful GRISM technique. These investigations will be referred to here only when they serve to illustrate the achievements or the limitations of the Schmidt telescopes. Our aim will thus be to establish the contributions to our present knowledge of the Magellanic Clouds that are based on Schmidt- (wide-angle-) telescope research, only. We will mainly deal with those areas where full use has been made of the special Schmidt-telescope characteristics.

2. DIRECT PHOTOGRAPHY OF THE MAGELLANIC CLOUDS

(1) Charts

(i) An *Atlas* in visual light, permitting the determination of accurate positions for objects with V < 18.5, has been prepared from Uppsala Southern Schmidt plates (Gascoigne, Westerlund 1961).

(ii) *Atlas* in B and V of the LMC and the SMC from ADH and Curtis-Schmidt plates, respectively, have been published (Hodge, Wright 1967, 1977); they contain lists and identifications of objects.

(iii) *Composite photographs* have been made by Johnson (1959a), by Walker *et al.* (1969), and, in colour, by Dufour and Gooding (1976).

Johnson used low-scale plates taken with the Meinel-Pearson camera. He concluded that the LMC consisted of two components: an asymmetrical Sc galaxy with its nucleus at 30 Dor, in front of an elliptical system. Walker *et al.* also remarked on the main components of the two Clouds. Since then, the "elliptical component" in the LMC and, in particular, the spiral structure with its nucleus at 30 Dor have appeared a number of times in the literature.

(2) HII regions

(i) *In the Clouds.* A distorted one-arm spiral was noted in the SMC by Rodgers (1959), who used the Meinel-Pearson camera to search the SMC for HII regions. His results agreed well with those by Nail *et al.* (1953) who used ADH red and blue plates. Johnson (1961), from Meinel-Pearson-camera plates, described the SMC as consisting of two components, one a dwarf elliptical, the other a contorted gaseous-magnetic arm with no nucleus.

Davies *et al.* (1976) catalogued the HII regions in the Clouds using long-exposure SRC-Schmidt plates taken with an Hα interference filter. This was the first extensive cataloguing of emission nebulae in the Clouds since Henize (1956).

Lasker (1979, 1980) used the Curtis-Schmidt to survey the Clouds in the light of [SII]λλ6713, 6731, Hα + [NII], and [OIII]λ5007, aiming at the numerous shell nebulae but also obtaining an overview of the excitation states of all nebulae.

(ii) *Between the Clouds.* The region between the Clouds was searched for emission regions by Johnson (1959b) with the Meinel-Pearson camera. He found a faint, sinuos ribbon curving across his field and suggested

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that it was probably an outlying portion of the Gum nebula. P.G. Johnson *et al.* (1982) obtained deep Hα plates along the Magellanic Stream with a wide-field camera (30°). They combined them with high-contrast prints from IIIa-J plates and with a deep Hα plate taken with the SRC Schmidt. A diffuse Hα region was found to be correlated with the Stream; the other detected filaments were faint and blue, possibly reflection nebulosity in the galactic plane (cf. de Vaucouleurs 1954, 1960). The filaments detected by Johnson (1959b) appear to coincide with a part of these filaments.

(3) Giant and supergiant shells in the Clouds

Westerlund and Mathewson (1966) found that the two supernova remnants, N49 and N63A, belonged to a shell-like structure forming the boundary of Constellation III in the LMC and centered on the emission nebula N55. They suggested that this might be a super-supernova remnant, and that many such remnants existed in the LMC. The third supernova remnant known at that time, N132D, was in a supergiant shell centered on Constellation II. The available Schmidt plates showed that these shells were the location for the formation of associations and clusters as well as for supernova explosions.

Shells of this kind and smaller ones have been discovered on the excellent interference-filter photographs taken with the SRC Schmidt (Goudis, Meaburn 1978). A total of 85 giant shells (20-260pc) are now known in the LMC, and 9 supergiant shells are proposed in the LMC and 1 in the SMC (Meaburn 1980).

(4) Dust in the Clouds

Surveys for dark nebulae in the Clouds have been carried out by Hodge (1972, 1974c) and by van den Bergh (1974). Hodge used Curtis-Schmidt and ADH plates in B and V for studying the LMC, and Curtis-Schmidt plates for the SMC. Van den Bergh used Curtis-Schmidt plates in R, V, B, and U of both Clouds. Not surprisingly, the two surveys agree well. The visual inspection is, however, a rather subjective method; for discovery the dust cloud has to be well silhouetted against the stellar population.

The absorption in the SMC has also been investigated with the aid of background galaxies. Hodge (1974a) identified 2 200 galaxies in an area of 85 square degrees, using Curtis-Schmidt plates. From their distribution he concluded that the dust in the SMC is distributed similarly to the neutral hydrogen (Hodge 1974b). The maximum absorption is $A_V = 1.3$ mag in the core of the SMC. His results confirm those previously obtained by Wesselink (see Hodge 1974a). They have been further confirmed by MacGillivray (1975), who used deep SRC Schmidt IIIa-J plates to reach B = 23 mag.

(5) Clusters in the Clouds

Several surveys for clusters in the Clouds have been carried out with Schmidt telescopes (Table 3). Discrepancies between the catalogues exist; they are generally due to the definition of an open cluster near the

Table 3. Surveys for clusters in the Magellanic Clouds.

Observer	Telescope	Clusters	Remarks
	In the SMC		
Kron (1956)	ADH	69	
Lindsay (1956b)	ADH	94	
Lindsay (1958)	ADH	116	
Westerlund, Glaspey (1971)	Uppsala S. Schmidt	18	In the Wing
Hodge, Wright (1974)	Curtis-Schmidt	220	
Brück (1975, 1976)	SRC Schmidt	330	
	In the LMC		
Shapley, Lindsay (SL) (1963)	ADH	897	
Lyngå, Westerlund (LW) (1963)	Uppsala S. Schmidt	483	In outer regions
Hodge, Sexton (HS) (1966)	ADH	1603	

plate limit. Lindsay's comments (1964) on the 184 LW clusters, which were not in the SL list in spite of being in the surveyed area, often agree with the LW definition of an old open cluster. It is difficult to identify a star-poor cluster also on large-scale plates. Thus, Brück's cluster E165 (1975) is in the field of NGC602, observed by Westerlund (1964a) with the Mt Stromlo 74-inch telescope in B and V to V = 20 mag. It was not noted by him as a cluster, though its 5 brightest stars were among those measured. 4 of them form a vertical main sequence down to V = 19.3 mag; the fifth and brightest has V = 17.15, B-V = +1.84. It may well be an open cluster of the age of M41 and M11 and typical for many of the faint open clusters in the Clouds.

It is important for judging the efficiency of Schmidt telescopes to establish the completeness of the surveys in Table 3. Hodge (1975), using the CTIO 1.5-m reflector, carried out deep surveys for clusters in fields in the LMC. He concluded that "the catalogues ... using Schmidt plates, are surprisingly complete". 65 percent of the clusters found in his deep search were already catalogued. By extending the surveys to B = 22.5 mag in 5 fields in the LMC with the aid of the CTIO 4-m reflector he found an average increase over the Schmidt surveys with a factor of 3 (Hodge 1980). The total number of clusters in the LMC was estimated to about 6 500.

The distribution of the clusters in the Clouds have been analyzed by a number of authors. For the SMC we refer to Brück (1975), who concluded that the disk defined by the clusters has the same effective size as that defined by the stars. There is, however, a lack of clusters in the centre of the SMC, noted also by Hodge (1974d).

The SMC is suspected of having a pronounced extention in depth; this has been seen in the HI distribution as well as for many classes of stellar objects. It has been given little consideration in the analysis of the cluster distribution. Hodge (1974d) examined the possibility of the cluster system being spheroidal, but came to the conclusion that the clusters are arranged in a plane together with the young stars. Azzopardi and Vigneau (1977) confirmed this: "the star cluster and ionized hydrogen distributions are well correlated with the O-B2 regions".

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The cluster distribution in the LMC was discussed by Lyngå and Westerlund (1963) who found an elliptical distribution, leading to a tilt of 45° for the LMC. This value would make the plane of symmetry of the LMC pass through the main body of the SMC, an attractive idea. The high value of 45° for the inclination is strongly objected to by de Vaucouleurs (de Vaucouleurs, Freeman 1973).

Using ADH and Curtis-Schmidt plates Hodge *et al.* (1970) estimated the magnitudes of the brightest stars in many LMC clusters. Hodge (1973) used 509 clusters with the brightest star brighter than V = 15.4 to discuss the evolutionary history of the cluster system. 60 percent of the clusters occur in groups isolated in space and time. The mean dimensions of the groups are about 1.5 kpc; the mean interval of formation is of the order of 10^6 yr. Undoubtedly, these groups of clusters are intimately connected with the super-associations, supergiant shells and bursts of star formation (Westerlund 1964b).

(6) Stellar associations in the Clouds

The SMC has few associations, the most pronounced ones are found in the Wing, from NGC 456-465 and out. The most complete listing of the associations in the LMC has been compiled by Lucke and Hodge (1970). They used ADH plates to identify 122 stellar associations. The dimensions vary from 15 to 350 pc. The definition of the boundaries of an association is always subjective, however, also in the LMC. Lucke (1974) has carried out B, V photometry on Curtis-Schmidt plates of the stars in the areas of the associations and produced very useful colour-magnitude diagrams.

(7) Star counts in the Clouds

(i) *The Wing of the Small Cloud* was searched for blue stars by Westerlund and Glaspey (1971) on Uppsala Southern Schmidt plates in U, B, V. Over 2 000 objects were identified and the structure of the Wing was outlined. Scattered blue stars, likely members of the SMC, were found outside the Wing.

(ii) *The disk and halo populations of the SMC* have been studied by Brück and Marşoglu (1978) on SRC Schmidt plates. They carried out B, V photometry to 21.2 mag in two fields in the eastern part of the SMC. Their field I, in the northern-most part of the Bar, has a young population, similar to the one in the Wing (cf. Westerlund 1964a). Their field II contains a halo population similar to the one near 47 Tuc (Tifft 1963).

Brück (1980) studied the radial distribution of 163 000 stars brighter than B = 21 mag in the south-west and north-east outer parts of the SMC. Disk stars and halo stars were separated. The disk stars are closely related with neutral hydrogen; the halo stars are strongly biazed towards the western parts of the SMC. This is somewhat surprising as previous studies have indicated that the old population may have its centroi to the east of the Bar (Johnson 1961, Westerlund 1970).

(iii) *The major spiral arm of the LMC.* The existence of a spiral structure in the LMC has been much debated. Dixon and Ford (1972) used Uppsala Southern Schmidt plates in B and V to divide 8 000 stars, located

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in the "major spiral arm" and more luminous than $M_V = -3.5$ mag, into four age groups. If the composition of the arm corresponded to the one expected from the density-wave theory, or if the arm had been formed by ejection (Schmidt-Kaler 1977), the youngest stars should be at the inner edge of the arm and the earlier generations successively displaced outwards. All four groups showed the same distribution over the spiral arm, the only possible variation being *along* the "arm" with the youngest stars further from the centre of the LMC. The distribution is better understood as that of a super-association, in particular as the youngest stars belong to a pronounced nebular complex.

(8) The variables in the Magellanic Clouds

The available space does not permit the extensive discussion that this important field of research deserves. Therefore, I will only mention some of the many lists.

Hodge and Wright (1967, 1977) have identified the variables found in the extensive searches carried out of the Harvard collection of plates. Other studies of variables based on ADH plates exist (Lindsay 1974, Butler 1978, also for references).

The distributions and the evolution of the variables in the Clouds have been discussed by Payne-Gaposchkin and Gaposchkin (1966) and by Gaposchkin (1972). The total number of variables then was 1592 in the SMC and 1830 in the LMC. Hodge and Wright expected this to be less than a half the number of existing variables.

For the recent search for novae in the Clouds with the Curtis-Schmidt I refer to Graham (1979).

3. OBJECTIVE-PRISM RESEARCH OF THE MAGELLANIC CLOUDS

The Magellanic Clouds have been observed with Schmidt telescopes equipped with objective-prisms with great success. As the sites of the southern Schmidt telescopes often have good or excellent seeing high-quality spectra have been obtained. Overlapping of spectra in the crowded regions of the Clouds has been a severe problem. The effect has been diminished by the use of very short spectra, either by going to very low dispersions or by limiting the spectral ranges with the aid of suitable filters.

Objective-prism spectra are usually not suited for radial-velocity determinations. (See for instance Butler, Norris 1969 and Fehrenbach 1970, Wood 1970.) The only radial-velocity determinations of survey-type of the Clouds are those by Fehrenbach and his collaborators with the aid of the GPO astrograph.

Most objective-prism plates have not been fully utilized. They have been inspected visually, the objects of interest identified and slit spectroscopy and/or photoelectric photometry carried out of some representative objects. Modern measuring techniques make, however, the plates useful for accurate spectrophotometry to an extent not previously possible.

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(1) Surveys for bright member stars of the Clouds

The identification of stellar members of the Clouds has been done by the determination of spectral types and luminosity classes and of radial velocities with the Fehrenbach technique (Table 4).

Table 4. Surveys for bright stellar members of the Clouds.

Observer	Telescope	No. of stars	Method	Remarks
	In the SMC			
Sanduleak (1968)	Curtis-Schmidt	169	Sp.class.	
Sanduleak (1969)	Curtis-Schmidt	47	Sp.class.	In Wing
Florsch (1972)	GPO astrograph	100	Rad.vel.	
Azzopardi, Vigneau (1982)	GPO astrograph	524	Sp.class.	
	In the LMC			
Sanduleak (1970)	Curtis-Schmidt	1272	Sp.class.	
Rousseau *et al.* (1978)	GPO astrograph	1822	Sp.class.	
Fehrenbach, Duflot (1982)	GPO astrograph	711	Rad.vel.	
Philip, Sanduleak (1979)	Curtis-Schmidt	312	Sp.class.	2 fields

A particular advantage of the radial-velocity technique over the spectral classification is that it permits the identification of A and F stars among the members of the Clouds; the classification gives generally only OB stars. An attempt to identify B7-G5 stars in the LMC by spectral classification on objective-prism Curtis-Schmidt plates was made by Stock *et al.* (1976). See, however, Fehrenbach, Duflot (1978).

(2) Surveys for red member stars of the Clouds

Spectral surveys in the near-infrared spectral region were introduced by Nassau and his collaborators (see Mavridis 1967 for references). The technique was applied by Westerlund (1961) in a study of the central regions of the LMC. The survey was extended to cover most of the LMC; catalogues of the identified stars have been puslished (Westerlund *et al.* 1978, 1981).

With the appearance of the fine-grain IIIa-J emulsion the range Hβ-5300 Å became available for objective-prism classification. It has been used on the Clouds by Sanduleak and Philip (1977), Rebeirot *et al.* (1983) and Prévot *et al.* (1983). Table 5 summarizes the data of the main lists.

The surveys of the SMC are few and mainly unpublished. There are no supergiants in the SMC later than M1 (Humphreys 1979). This has been confirmed by Prévot *et al.* (1983); their stars are all in the range K5-M1.

A comparison of the two catalogues of carbon stars in the LMC shows only 75 objects in common. This is mainly due to the fact that identification by the near-infrared CN bands gives cooler stars than the one by the green C_2 bands. (Cf. Richer *et al.* 1979).

Table 5. Lists of red stars in the Clouds.

Observer	Telescope	MI stars	C stars	Remarks
	In the SMC			
Sanduleak (unpubl.)	Curtis-Schmidt	101		
Sanduleak, Philip, Albers (unpubl.)	Curtis-Schmidt		yes	
Prévot *et al.* (1983)	ESO Schmidt, GPO	199		+ 23 gal.st.
	In the LMC			
Sanduleak, Philip (1977)	Curtis-Schmidt	609	474	
Westerlund *et al.* (1978, 81)	Uppsala S. Schmidt	480	302	+ 52 gal.M
Rebeirot *et al.* (1983)	ESO Schmidt, GPO	839		

The three lists of supergiants in the LMC show also certain discrepancies. The reason appears to be in the classification criteria: In the near-infrared the definition of class MO is difficult in low dispersion; gradients are difficult to estimate visually; late K stars may be included when the green TiO bands are used.

The total number of M supergiants in the LMC from the three lists amounts to 894 objects (Rebeirot *et al.* 1983). The 626 carbon stars listed represent only the bright part of this class. GRISM surveys have led to the detection of a large number of fainter carbon stars, and to the discovery of more objects in the crowded regions of the LMC. Similar results exist for the SMC.

A number of M giants are listed by Westerlund *et al.* (1981) as possible members of the LMC. Blanco and McCarthy (1975) used the Curtis-Schmidt for a near-infrared survey of a field in the LMC with a dispersion of only 6 700 Å/mm. Over 800 late M stars were seen.

(3) Surveus for emission-line objects in the Clouds

The surveys for emission-line objects in the Clouds are still rather incomplete. The most extensive ones are listed in Table 6.

Table 6. Emission-line objects in the Clouds.

Observer	Telescope	Objects in		Remarks
Henize (1956)	MtWilson 10"	172	LMC	+ 415 neb.
		65	SMC	+ 117 neb.
Lindsay (1961)	ADH	593	SMC	49 P or P?
Lindsay (1963)	ADH	358	LMC	
Andrews, Lindsay (1964)	ADH	446	LMC	
Bohannan, Epps (1974)	Curtis-Schmidt	446	LMC	all new iden.

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(4) Planetary nebulae in the Clouds

Table 7 lists surveys for planetary nebulae in the Clouds which have been carried out with Schmidt telescopes.

Table 7. Surveys for planetary nebulae in the Clouds.

Observer	Telescope	Number of P:s
	In the SMC	
Lindsay (1955)	ADH	17
Lindsay (1956a)	ADH	20 + 9P?
Lindsay (1961)	ADH	30 + 19P?
Sanduleak *et al.* (1978)	Curtis-Schmidt	28
	In the LMC	
Westerlund, Rodgers (1959)	Uppsala S. Schmidt	34
Lindsay, Mullan (1963)	ADH	65 + 44 no continuum
Westerlund, Smith (1964a)	Uppsala S. Schmidt	42
Sanduleak *et al.* (1978)	Curtis-Schmidt	102

Jacoby (1983) has discussed these surveys and related them to his deep samples with the CTIO 4-m telescope (Jacoby 1980). He concludes that the total numbers of planetaries are 285 ± 78 in the SMC, and 996 ± 253 in the LMC. The estimate for the SMC is in fair agreement with the value of 300 derived by Henize and Westerlund (1964), whereas the one for the LMC is about twice as large as the value of 450 derived by Westerlund and Smith (1964a). The estimates are sensitive to the definition of the magnitude interval used for the counts.

Sanduleak *et al.* (1972), using unwidened Curtis-Schmidt objective-prism spectra with a dispersion of 420 Å/mm at Hα, resolved the [NII] line λ6584Å and Hα, and found the SMC planetaries to be nitrogen deficient.

The surveys of the Clouds for planetaries have also led to discoveries of "compact HII regions" (see Henize, Westerlund 1964, Davies *et al.* 1976, Sanduleak, Philip 1977, and Sanduleak *et al.* 1978).

(5) Surveys for Wolf-Rayet stars in the Magellanic Clouds

A summary of the discoveries of Wolf-Rayet stars in the Clouds is given in Table 8. References to additional papers may be found in those given in the Table.

Westerlund (1961) pointed out that the Wolf-Rayet stars in the colour-magnitude diagrams of the clusters and associations always were at the turn-off points. This fact should be considered in attempts to understand the range of 3 mag spanned by the early WN stars as well as by the late ones. Most likely all Wolf-Rayet stars have formed in associations; the older stars in an association may be found in its outer parts, and thus also many evolved Wolf-Rayet stars. There should, however, be a cut-off for the Wolf-Rayet stars belonging to the youngest Population I in

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Table 8. Surveys for Wolf-Rayet stars in the Clouds.

Observer	Telescope	Number of W-R:s	Remarks
	In the SMC		
Azzopardi, Brysacher (1979)	GPO astrograph	8	
	In the LMC		
Westerlund, Rodgers (1959)	Uppsala S. Schmidt	50	
Westerlund, Smith (1964b)	Uppsala S. Schmidt	58	
Fehrenbach *et al.* (1976)	GPO astrograph	78	all new WN3,4
Breysacher, Azzopardi (1982)	GPO astrograph	101	

the LMC. The value of V = 15 mag, proposed by Westerlund and Smith (1964b) should be increased somewhat following the discovery of the faint WN3 and WN4 stars. This does, however, not change the evolutionary pattern proposed by them. It is now also attractive with the proposed evolutionary pattern, WN7 → WN3 (see IAU Symposium No. 99). It is more difficult to see, from the stars in the LMC, how this sequence may continue into the WC:s.

4. CONCLUSIONS

The surveys of the Magellanic Clouds with wide-field telescopes, in particular Schmidt telescopes, have during the past three decades made fundamental contributions to our knowledge of the Clouds, their structure and their evolution. They have also identified objects that have served for determining the chemical composition of the various populations of the Clouds as well as for studies of the kinematics and dynamics of the Clouds and of the Magellanic System. It is to be expected that "Schmidt"-surveys in the future will, with the aid of suitable filter-, detector- and reduction-techniques, reach fainter objects as well as overcome the problems of overlapping in the crowded regions.

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