energy within a flux tube should be significantly enhanced compared with the surrounding field-free regions. This would provide a mechanism for a two-stream radiative model, because the flux-tubes would reach the critical temperature of 4,000 K, and then tend to higher temperatures, while the surrounding plasma could remain comparatively cool, essentially below 4,000 K.

If this mechanism is indeed important, the consequences for those trying to model chromospheric lines either from the Sun itself or from solar-type stars, are certainly significant. As far as the Ca II and Mg II resonance lines are concerned, the part of the line formed in the "chromosphere", which is essentially the emission core, will be diluted by a purely "photospheric" absorption line, essentially the very broad surrounding feature, which in fact comes from the rather large bulk of cool material which co-exists outside the flux tubes but at the same height. The emission cores will come principally from those regions where the flux tubes are most concentrated, which, in the case of the Sun, implies the supergranular boundaries and the plage regions, and the broad absorption wings will come from an entirely different pressure and temperature regime. One way to test the idea on the Sun, is by careful centre-to-limb measurements of the Ca II profiles, since near the limb the cooler more opaque regions will have a greater effect, and the absorption trough should deepen relative to the emission core. Such a test will be necessary before serious attempts to apply two-stream modelling to stars can be contemplated, but solar measurements of this type are not exceptionally difficult.

7. The Use of Observations at High Spectral Resolution

According to the "classical" method of dealing with high resolution profiles, one starts by using the K1 and H1 minima in intensity to determine the stellar chromospheric temperature minima, the widths of the emission core to establish a microturbulence parameter to insert within the model, and the emission fluxes to compute the distribution of heating and cooling rates. A simple combination of the photospheric and chromospheric components (not neglecting the effects of non-LTE and partial redistribution) then sets up the line profile. By combining information from lines formed at different heights, one can then hope for self-consistent models. Now we are faced with a situation in which not only we must take into account the unknown (and almost unknowable) field of microturbulence with height, but also the streaming velocity fields inside the structures that produce the lines. We must take into account the role played by inhomogeneities, which appears to be dominant, and we must be sure that any interstellar effects in the line profile data from the star are well and truly eliminated. We can then begin to apply models which allow for non-LTE and partial redistribution effects. Only at that point can we begin to realize our goal, which is to parametrize those factors which lead to the deposition of energy within chromospheres, before going on to show how they vary with the mass, age, chemical composition, and rotation rate of a star.

CASPEC and IUE: A Perfect Match

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As not all readers of the *Messenger* may be familiar with the lingo of today's astronomers, we shall first try to explain the acronyms used in the title: CASPEC stands for "Cassegrain Echelle Spectrograph", IUE for "International Ultraviolet Explorer". Both are modern and very successful instruments for high resolution spectroscopy of astronomical objects. In both devices the high resolution is achieved using an echelle design, i.e. by dispersing the light with two perpendicularly oriented diffraction gratings, one of which is operated at high ($\sim 10^2$) orders. (For more technical details see the articles by D'Odorico et al. in *Messenger* No. 33 and by Le Luyer et al. in *Messenger* No. 17.) There are also some differences between CASPEC and IUE: CASPEC was developed as an auxiliary instrument for the ESO 3.6 metre telescope at La Silla. It can be used in the spectral range $\sim$3500 Å to 9500 Å. The IUE spectrograph circles the earth as an artificial satellite at a mean distance of about 36,000 km above the equator and is fed by a telescope of only 0.45 metres aperture. As its name implies, IUE is used at UV wavelengths (about 1100 Å to 3200 Å) where ground-based observations are impossible because of the strong UV absorption in the earth's atmosphere.

During the past six years our group has been using IUE for investigations of a variety of different astronomical objects. During this time we found the IUE satellite to be particularly valuable for studies of distant blue supergiant stars. There are several reasons to investigate extreme blue supergiants: First, these stars are at the upper limit of stellar luminosities and their properties allow important insights into the problems of stellar stability. Secondly, because of their extreme brightness such stars are easily observed in nearby extragalactic stellar systems and therefore can be used to probe the physical conditions in other galaxies. The potential of these objects is illustrated by the fact that the absolute brightness of a single extreme blue supergiant typically exceeds that of a globular cluster or even that of a dwarf galaxy containing millions of stars.

IUE is particularly useful for studying blue supergiants as these stars emit most of their radiation just in the IUE spectral range. Hence, these objects can be observed at high spectral resolution even at the distance of the Magellanic Cloud galaxies. In fact, in spite of the much larger telescopes at La Silla, before 1983 we were often unable to match the high resolution of IUE spectrograms of bright Large Magellanic Cloud (LMC) stars with ground-based spectroscopic observations at longer wavelengths. This was unfortunate since at different wavelengths we observe different layers of these objects and only observations over a large spectral range allow to deduce a complete picture of their physical structure: In most cases the UV observations result in information on the dense and hot parts of the expanding envelope, while measurements in the visual and red provide data on the deeper, more static, layers, but also (using forbidden-line profiles) on the rarified outermost regions. CASPEC therefore greatly improved the efficiency of spectroscopic studies of such stars. In the following we shall describe in a few examples how CASPEC and IUE can be combined for obtaining a maximum of physical information.

The "Star" HDE 269599

This object derives its name from its number in the **H**enry **D**raper **E**xtension star catalog, where its position was pub-

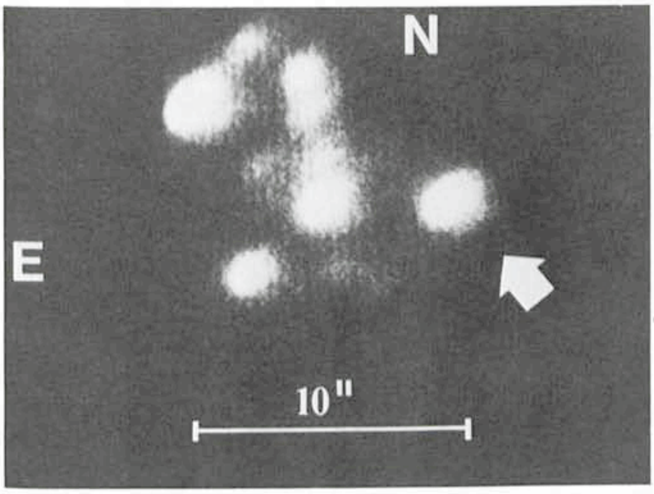

Fig. 1: *The LMC objects HDE 269599. The arrow indicates the emission line component S 111.*

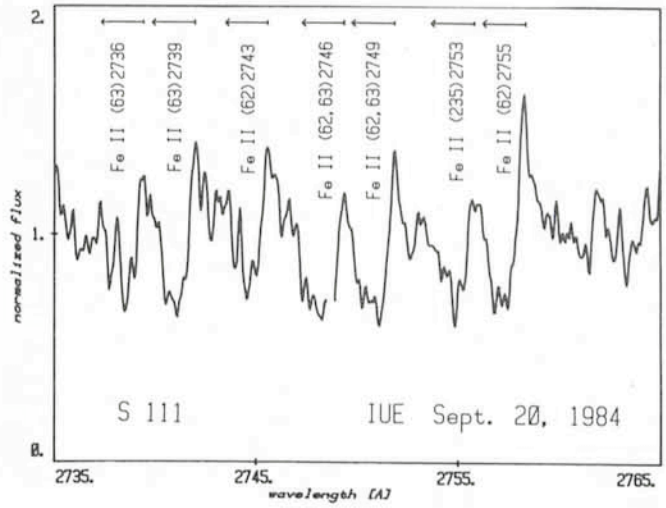

Fig. 2: *Examples of P Cygni profiles in the UV spectrum of S 111.*

lished by Annie J. Cannon in 1936. Cannon gave an approximate magnitude and spectral information based on objective prism plates obtained in 1925 at Chuquicamata, Chile. The spectrum must have looked rather strange, since it is one of the relatively few cases where Cannon did not dare to assign an explicit spectral type. Instead she only stated that the spectrum was "peculiar". In 1956 Karl Henize found HDE 269599 to be an emission line star and gave it the additional catalog designation S 111. The first slit spectrogram of this star was published by Feast, Thackeray, and Wesselink in 1960. From the observed radial velocity they were able to prove that this object was a very bright member of the LMC galaxy. In their (**R**adcliffe Observatory) catalog the star also acquired the additional designation R 105. The Radcliffe spectrogram showed a B-type absorption spectrum without emission lines. However, Feast et al. noted that HDE 269599 was not a single star but a very compact small cluster, which was only partly covered by the spectrograph slit. Further slit spectrograms obtained by A. Ardeberg et al. at ESO (cf. *Astronomy and Astrophysics Suppl.* **6,** 1972) showed that the emission line spectrum was produced by a component at the SW edge of the compact cluster. More recently Shore and Sanduleak (*Astrophysical Journal Suppl.* **55,** 1984) confirmed the emission line character of HDE 269599 = S 111, but stated that this object was not identical with the (B type star?) R 105. On the other hand, on a low resolution IUE spectrogram Shore and Sanduleak found S 111 to have a pure B-type absorption spectrum in the UV.

Although in such cases new observations usually only increase the confusion, we recently obtained additional spectrograms. To understand our results, let us first look at Fig. 1, where we reproduce an image of HDE 269599 as seen by the television camera of the ESO 3.6 m telescope guiding system. Obviously HDE 269599 is a highly compact cluster of at least ten high luminosity stars. Its diameter is about 10 arcseconds, corresponding to 2.5 pc at the distance of the LMC. Our CASPEC observations confirmed that the emission line spectrum is produced by the bright star at the SW edge of the cluster. For clarity henceforth only this component will be called S 111. The second visually bright component of HDE 269599, the star at the NE edge of the object, was found to show a normal B-type absorption spectrum as observed by Feast et al. Therefore we suggest to reserve the designation R 105 for this latter component of HDE 269599.

Observing S 111 (as defined above) with IUE was less easy, as the IUE field camera, which produces 8" pixels, cannot resolve HDE 269599 into its components. Nevertheless, with some tricks and the kind help of the Villafranca IUE observatory controller, Dr. Willem Wamsteker, it was possible to isolate S 111 for obtaining a high resolution UV spectrogram. This spectrogram showed that S 111 is an emission line object in the UV as well.

Apart from its history, S 111 also shows a particularly interesting emission line spectrum: In the UV many spectral lines show pronounced P Cygni profiles, which obviously are produced in a dense expanding envelope. Examples are the moderately strong (non-resonance) Fe II lines reproduced in Fig. 2. Sometimes the blue absorption components seem to show a double structure with a strong low velocity and a weaker high velocity component. However, the signal-to-noise ratio of the IUE spectrogram is too low to clearly establish this structure. On the other hand, this type of line profile becomes obvious on the CASPEC spectrograms, as illustrated e.g. by the H_γ line profile in Fig. 3. But much more interesting is a comparison of these P Cygni profiles with the structure of the forbidden lines, like the [Fe II] λ 4359 in Fig. 3: While the P Cygni lines indicate very high wind velocities of up to 600 km s^{-1}, the forbidden lines, which can be formed only in the rarified outer regions of the envelope, indicate a much lower velocity dispersion. From the unblended strong [O I] λ 6300 line reproduced in Fig. 4 we obtain a velocity range

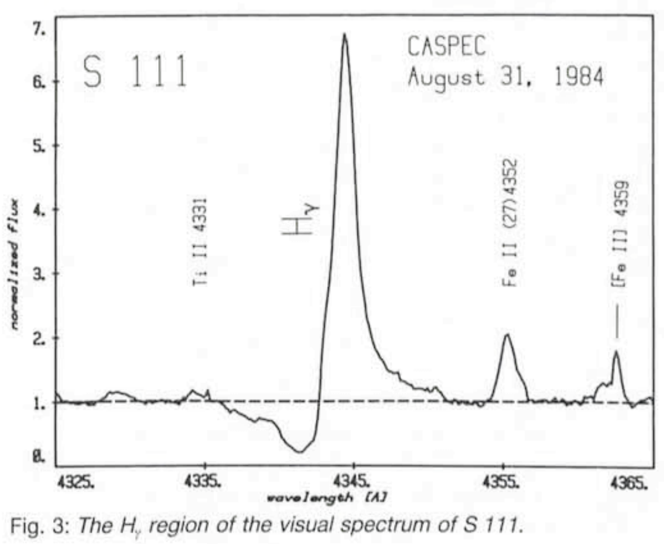

Fig. 3: *The H_γ region of the visual spectrum of S 111.*

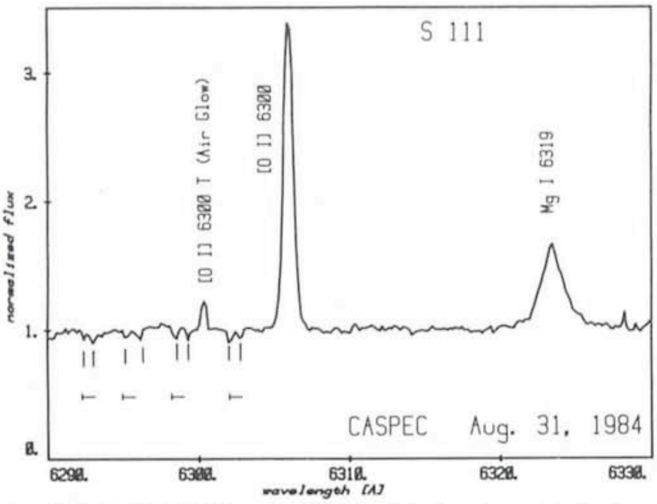

Fig. 4: *The [O I] λ 6300 line of S 111. The "T"s denote spectral features produced by the terrestrial atmosphere. The wavelength shift between the stellar and airglow emission results mainly from the orbital motion of the solar system in our galaxy.*

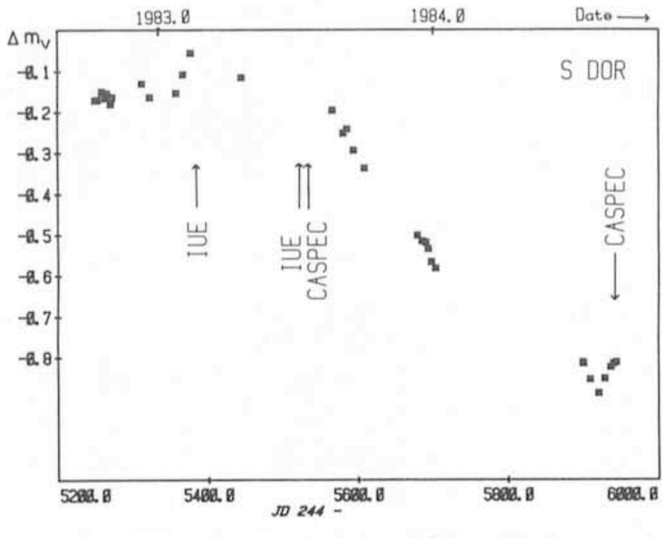

Fig. 6: *The recent brightness evolution of S Dor. This lightcurve is based on the "long-term photometry of variables" programme organized at ESO by Ch. Sterken. Δm_v denotes the visual magnitude difference relative to an (arbitrarily chosen) constant comparison star.*

which is less than 10 % of the expansion velocity derived from permitted lines. In principle there are two possible explanations of this discrepancy: Either the wind is strongly decelerated (which for various reasons appears unlikely) or the stellar wind and circumstellar envelope of this star show a strongly non-spherical geometry, as deduced earlier from similar arguments for the related LMC emission star R 126. (For details see Zickgraf et al., *Astronomy and Astrophysics,* in press.) From a detailed spectral analysis, which has just been started, we expect for S 111, with its rich emission spectrum, firmer and more quantitative conclusions than were possible for R 126.

R 127 and S Doradus

These two variable stars of the "S Dor" or "Hubble-Sandage" class are also members of the LMC galaxy. We now believe that S Dor variables are very hot (typically OB-type) supergiants with variable and sometimes extremely dense and optically thick stellar winds. Although their bolometric luminosity seems to remain essentially constant, the variations of the wind optical depth results in changes of their continuum energy distribution and consequently in variations of the visual brightness. Although this model has been developed from earlier observations of other stars, it gained its strongest support from the discovery of the S Dor nature of R 127. As described by Wolf and Stahl in the *Messenger* No. 33, until

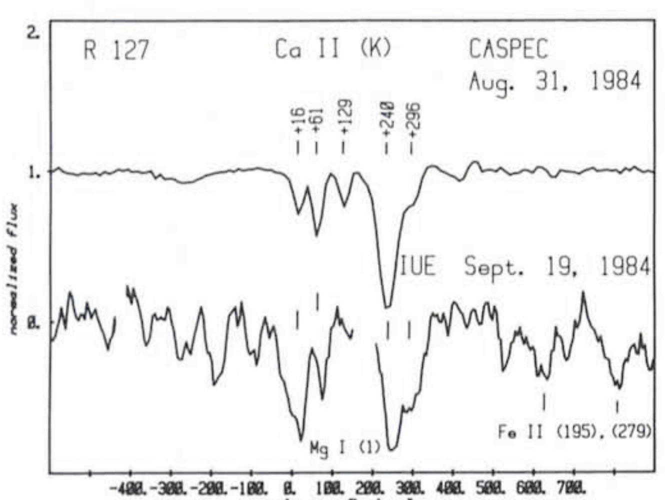

Fig. 5: *A comparison of the velocity structure of the Ca II (K) λ 3934 and the Mg I λ 2852 absorption profiles of R 127. The components are labelled by their heliocentric radial velocity (in km s^{-1}).*

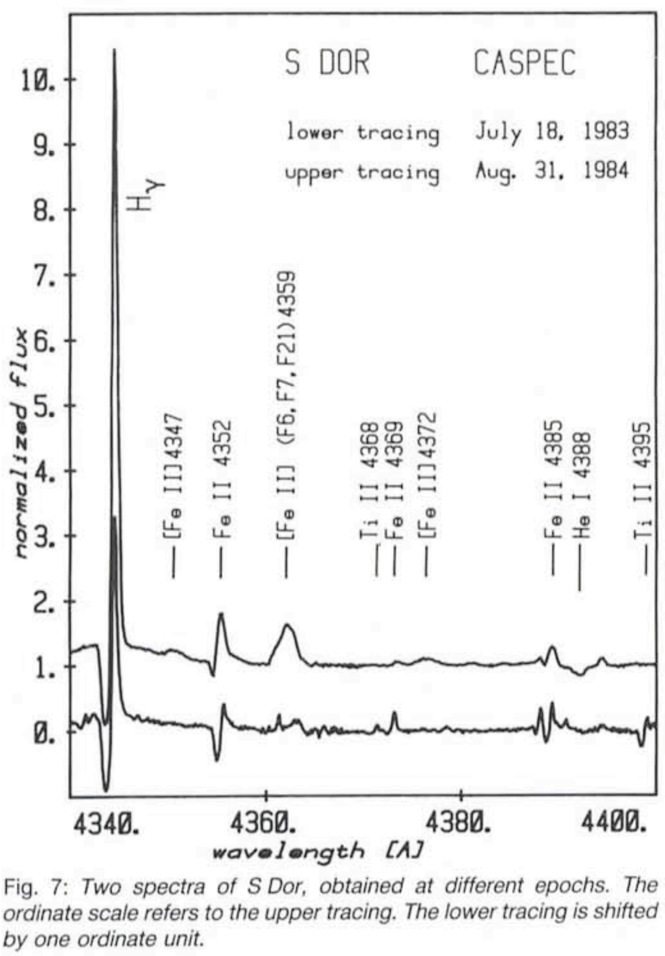

Fig. 7: *Two spectra of S Dor, obtained at different epochs. The ordinate scale refers to the upper tracing. The lower tracing is shifted by one ordinate unit.*

about 1977 R 127 had been a well classified O star. In 1982 it was discovered that R 127 had developed an S Dor type envelope which resulted in a considerably higher visual brightness. During the past two years this envelope has become even more pronounced and R 127 has now become the second brightest star in the LMC. As m_v is still increasing, R 127 may soon become the visually brightest star of this galaxy.

As described by Wolf and Stahl in the article quoted above, on IUE high resolution spectrograms the envelope absorption lines and P Cygni absorption components of R 127 showed a complex multiple structure, indicating discrete mass loss events. As illustrated by Fig. 5 with CASPEC it has now become possible to observe these features also in many additional lines in the visual spectral range. These observations will certainly help to clarify the nature of this phenomenon and the mass loss mechanism of the S Dor stars in general.

A final example of the potential of CASPEC observations is presented in Fig. 7, where we give sections of two CASPEC spectrograms of the star S Doradus itself, obtained at different epochs. During the past 13 years S Dor has been in its maximum state. However, in August 1983 its visual brightness started to decrease again (cf. Fig. 6) and it seems now to be on its way towards its minimum state. Fortunately, just before the star began to dim significantly, a first CASPEC spectrum of S Dor could be obtained while the instrument was still being tested at the telescope. Recently (13 months later and after the star had become fainter by $\Delta m_v \approx 0.8$) the second spectrum was obtained.

As shown by Fig. 7 the brightness changes are accompanied by characteristic spectral changes: With decreasing visual brightness (i.e. decreasing wind density) the (blue-shifted) envelope absorption features decrease rapidly, some envelope lines (like the Ti II lines) simply disappear, while the Balmer emission, the low density forbidden lines, and the unshifted high excitation "photospheric lines" (like He I λ 4388) increase in strength. Although some of this behaviour was known before, only the high spectral resolution and linearity of CASPEC allows to determine these changes without distortions. Even a slight decrease of the resolution would result in a partial fill-in of the deep envelope absorption components of H_γ by the adjacent very strong emission component.

Most of the data described above have been obtained only very recently and this paper resulted from our excitement during a first quick look at the reduced spectrograms. But we are convinced that the usefulness of the combination of high resolution spectrograms obtained with IUE and CASPEC will become even more evident when all our data are fully analyzed. We also note that the potential of such coordinated space and ground-based spectroscopic programmes will become even greater when the Space Telescope and future UV satellites allow high resolution UV observations of astronomical objects which are beyond the limiting magnitude of the IUE.

Catching Carbon Stars in the Baade's Windows

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Near-infrared objective prism surveys at low dispersion (1700 to 3400 Å mm^{-1}) using Schmidt telescopes have been extensively used to detect M-, S- and C-type stars in the galactic equatorial zone, and in other strategically selected regions of the Milky Way. The detection techniques have been perfected by Nassau and his associates (Nassau and Velghe, 1964, *Astrophysical Journal* **139,** 190) during their survey, at Cleveland, of the northern part of the Milky Way. These techniques are based on the identification of a number of typical molecular bands (TiO, CN, LaO, VO) that fall in the 6800–8800 Å spectral range, and which are used to classify M-, S- and C-type stars (Mavridis, 1967, Coll. on Late Type Stars, p. 420). Using the same method, partial or entire near-infrared surveys of the southern Milky Way have been carried out by Blanco and Münch (1955, *Bol. Obs. Tonantzintla y Tacubaya* **12,** 273) at Tonantzintla, Smith and Smith (1956, *Astronomical Journal* **61,** 273) at Bloemfontein, and later by Westerlund (1971, *Astronomy and Astrophysics Suppl.* **4,** 51; 1978, ibid. 32, 401) with the Uppsala Schmidt telescope at Mount Stromlo Observatory.

These near-infrared, low dispersion spectra surveys allowed the space distribution of the most recognizable red stars to be studied. These stars are essentially all S stars, or M and C stars later than M2 and C2. It is important to note that the observed distributions are affected by biases due to inhomogeneities in the interstellar absorption and to luminosity differences amongst the various types of stars. Also, the limiting magnitude to which the various red stars can be classified, and thus identified, varies according to their type: in particular, C stars can be detected almost to the limiting magnitude of the plates. Because they are rather luminous – all C and S stars and the majority of the M stars are giants – and less affected by the interstellar absorption in the near-infrared, the red giant stars lead to deep surveys of our Galaxy. The study of the distribution of the C stars as a function of the galactic latitude shows that these stars, which are strongly concentrated in the galactic plane, form the coolest component of the galactic disk population. Local variations in the distribution of the carbon stars with galactic longitude are due to known dark clouds. Nevertheless, it is possible to assert that C stars are inclined to cluster and are correlated with the spiral structure. Their number decreases strongly toward the galactic centre while the number of the late-type M stars increases (Westerlund, 1964, IAU Symp. No. 20, 160).

The three fields selected by Baade (1963, *Evolution of Stars and Galaxies,* p. 277) in the Sagittarius Star Cloud as relatively low absorption regions – currently named NGC 6522 ($l = 0\overset{\circ}{.}9$; $b = -3\overset{\circ}{.}9$), Sgr I ($l = 1\overset{\circ}{.}4$; $b = -2\overset{\circ}{.}6$), Sgr II ($l = 4\overset{\circ}{.}2$; $b = -5\overset{\circ}{.}1$) – allow this trend to be confirmed. A first attempt to identify red giant stars in the galactic nuclear bulge, namely in the clear region near the globular cluster NGC 6522, known as Baade's window, was made by Nassau and Blanco (1958, *Astrophysical Journal* **128,** 46). Owing to the unfavourable scale of the Schmidt telescope used to prospect so crowded a region, they found numerous late-type M stars. McCarthy (1983, *Mem. Soc. Astron. Ital.* **54,** 65) reports that a new near-infrared survey of this region was carried out by Blanco and Hoag as early as 1975 with the grism technique (Bowen and Vaughan, 1973, *Publ. Astron. Soc. Pacific* **85,** 174) at the prime focus of the CTIO 4 m telescope. Using this observational material (region of 0.12 square degree) Blanco et al. (1978, IAU Symp. No. 80, p. 33) found about 300 M stars later than M5 and just one C star. More recently, a preliminary survey by McCarthy and Meier (see McCarthy, 1983) of the Sgr I Baade's window