through the CNO cycle, stellar population) cannot simply be drawn from metal abundances.

The optical spectra hardly contain metal lines, whereas in the UV a large number of lines is present. High resolution IUE spectrograms of 3 sdOB stars (HD 149382, Feige 66 and Feige 110) have been analysed with the result that silicon is deficient in all 3 stars, by as much as a factor 40,000 (!) in HD 149382. Carbon likewise is deficient in Feige 110, by a factor 300,000 (!), but only moderately deficient (factor of ~ 100) in the 2 other stars, whereas nitrogen appears to be (nearly) solar in all 3 stars. In contrast to the sdOB's, silicon appears (almost) solar in the subdwarf B stars.

Some of these strange abundance anomalies can be understood, for instance the deficiency of silicon: at temperatures occurring near the bottom of the photospheres in subdwarf OB stars, silicon is ionized to Si^{4+}. This ion has a noble gas electron configuration with small absorption cross sections. Radiation that otherwise would force the ion upwards can no longer balance gravitation. As a consequence, the ion sinks below the photosphere (Baschek et al., 1982). A complete and quantitative theory, however, is lacking, and one is presently left with a more or less confusing picture of strange abundance patterns. All the information hidden there and being of great potential use in defining the momentary and past state of the photospheres in those subdwarfs, cannot be exploited at present.

Evolution

From the (g, T_{eff}) diagram (see above) it was concluded that subdwarf B and OB stars form the blue extension of the horizontal branch towards higher temperatures. After helium core exhaustion they evolve at constant gravity and eventually reach the domain of subdwarf O stars. This means that the (g, T_{eff}) domain, which is occupied by subdwarf O stars, is also shared by evolved subdwarf B stars. How can these two classes be separated?

It is known that subdwarf O stars are helium rich. They have temperatures above 40,000 K (Hunger and Kudritzki, 1981). At these temperatures, the He II convection zone extends up to the photosphere and thus inhibits diffusion which would dilute helium. But once helium is depleted as in our sdB sample, He II convection cannot work and hence a subdwarf B star, when crossing the 40,000 K boundary, stays helium poor (Groth and Kudritzki, 1983). For subdwarf O stars, the situation is different: they start from the (canonical) horizontal branch, i.e. with masses between 0.5 and 0.6 $M_\odot$, and hydrogen-rich shell masses in excess of 0.02 $M_\odot$. They move upwards in the (g, T_{eff}) plane along a "Sweigart" track, attaining gravities which are too small for diffusion, and eventually experience shell flashes. When they reach the sdO domain, they have already mixed helium to the surface and thus convection becomes possible. This means true subdwarf O stars can be distinguished from evolved sdB (and sdOB) stars by their helium content. So far, 3 objects are known whose effective temperatures are in excess of 40,000 K and whose helium contents are subsolar (Heber and Hunger, in preparation). Those are, according to the above described picture, old evolved subdwarf B stars.

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Stellar Metallicity Gradient in the Direction of the South Galactic Pole Determined from Walraven Photometry

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Introduction

It has been known for a while that the stellar population in our Galaxy changes drastically as a function of distance from the galactic plane—the disk is composed mostly of relatively young stars with solar metal abundances and small velocity dispersions whereas the average metallicity drops and the age increases as we look at stars deeper in the halo. These findings were interpreted by Eggen et al. (1962, *Astrophysical Journal* **136,** 748) in terms of their rapid collapse model of the protogalaxy and the subsequent formation of the disk. However, for a detailed model of the evolution of the Galaxy we need a much broader observational basis, viz. knowledge of the parameters stellar density, metallicity, age and velocity dispersion as a function of distance from the galactic plane. Several attempts have been made to reach this goal.

The Basel halo programme has been described and initiated by Becker (1965, *Zeitschr. f. Astrophys.* **62,** 54). The aim was to study the stellar density function in different halo directions (mostly Selected Areas) in a meridional plane perpendicular to the disk containing the galactic centre and the sun. The programme is based on deep Palomar Schmidt plates taken with the three filters of the RGU system. It is well known that metal-poor stars show UV excesses relative to stars with solar abundances. In the RGU system, this effect is even more pronounced than in the UBV system, and it can be used to separate the metal-poor halo stars from the solar abundance disk stars statistically. The metallicities of the halo stars in the Basel Survey have been estimated on the basis of their colours by Trefzger (1981, *Astronomy and Astrophysics* **95,** 184).

The nearby field star population at the galactic poles has been investigated by Blaauw and Garmany (1975, in Proceedings of the Third European Astronomical Meeting, E. K. Kharadze [ed.], Tbilisi, p. 351) and Blaauw (1978, in Astronomical Papers dedicated to B. Strömgren, Reiz and Andersen [eds.], p. 33); the observations were carried out using the Strömgren and Walraven photometric systems. In the latter paper it was shown that Walraven photometry is excellently suited to determine metallicities and luminosities of F and G type stars. However, the measurements did not go fainter than $V = 12^m$, reaching distances of at most 700 pc from the plane.

The observations described here—a joint Swiss-Dutch undertaking—aim at determining the relation between stellar metal abundance and distance from the galactic plane in a wider solar neighbourhood. By using the Basel RGU Survey for the selection of the programme stars (of type F and G), we can now extend the earlier photoelectric work to larger distances. On the other hand, the Walraven photometry allows to put the extensive Basel RGU data on a more accurately calibrated photoelectric base. We discuss our first preliminary results, obtained from two observing runs on La Silla in December 1981 and November 1982 with the Walraven photometer at the Dutch 90 cm telescope.

The Walraven Photometric System

For a description of the Dutch telescope on La Silla and the Walraven VBLUW photometer we refer to an article by Lub (1979, *The Messenger* No. **19,** 1). The stellar light is measured simultaneously through five passbands of intermediate width at the following effective wavelengths: V: 5420 Å, B: 4270 Å, L: 3850 Å, U: 3620 Å and W: 3230 Å. Since most of our programme stars are too faint and too cool to give measurable W signals, we are left in this programme with one magnitude (V) and the three independent colour indices (V-B), (B-L) and (L-U).

Assuming negligible or at most small foreground reddening in the directions of the fields investigated (see below), VBLUW photometry enables us to separate the effects of temperature, metallicity and gravity for intermediate-type stars (Lub and Pel, 1977, *Astronomy and Astrophysics* **54,** 137, see also Pel, 1982, *The Messenger* No. **29,** 1). The colour index (V-B) is a measure of stellar effective temperature, and the indices (B-L) and (L-U) are sensitive to line blanketing (mostly from Fe and other metals) and surface gravity (log g), respectively. This is illustrated in Fig. 1 by the theoretical colours computed from Kurucz model atmospheres (Kurucz, 1979, *Astrophysical Journal Suppl.* **40,** 1). By combining the two diagrams of Fig. 1 we can estimate for each programme star the three parameters temperature, gravity and metallicity: The (V-B)-(B-L) diagram provides an almost gravity-independent temperature-metallicity grid, whereas the Balmer jump index (L-U) in the other diagram yields the gravity almost independently of the metallicity.

Semi-empirical Calibration in Terms of Temperature, Metallicity and Gravity

We do not want to calibrate the diagrams solely on the basis of the computed colours from model atmospheres because it is known that these still fail to reproduce accurately the colours of cooler stars, especially in the blue and ultraviolet spectral region. We therefore decided to observe nearby F, G and K stars with known physical parameters from detailed spectroscopic analyses and used the data compiled by Cayrel de Strobel and Bentolila (1983, *Astronomy and Astrophysics* **119,** 1).

We constructed a semi-empirical calibration of the (V-B)-(B-L) diagram by combining the theoretical Kurucz colours with observations of field stars covering a wide range in

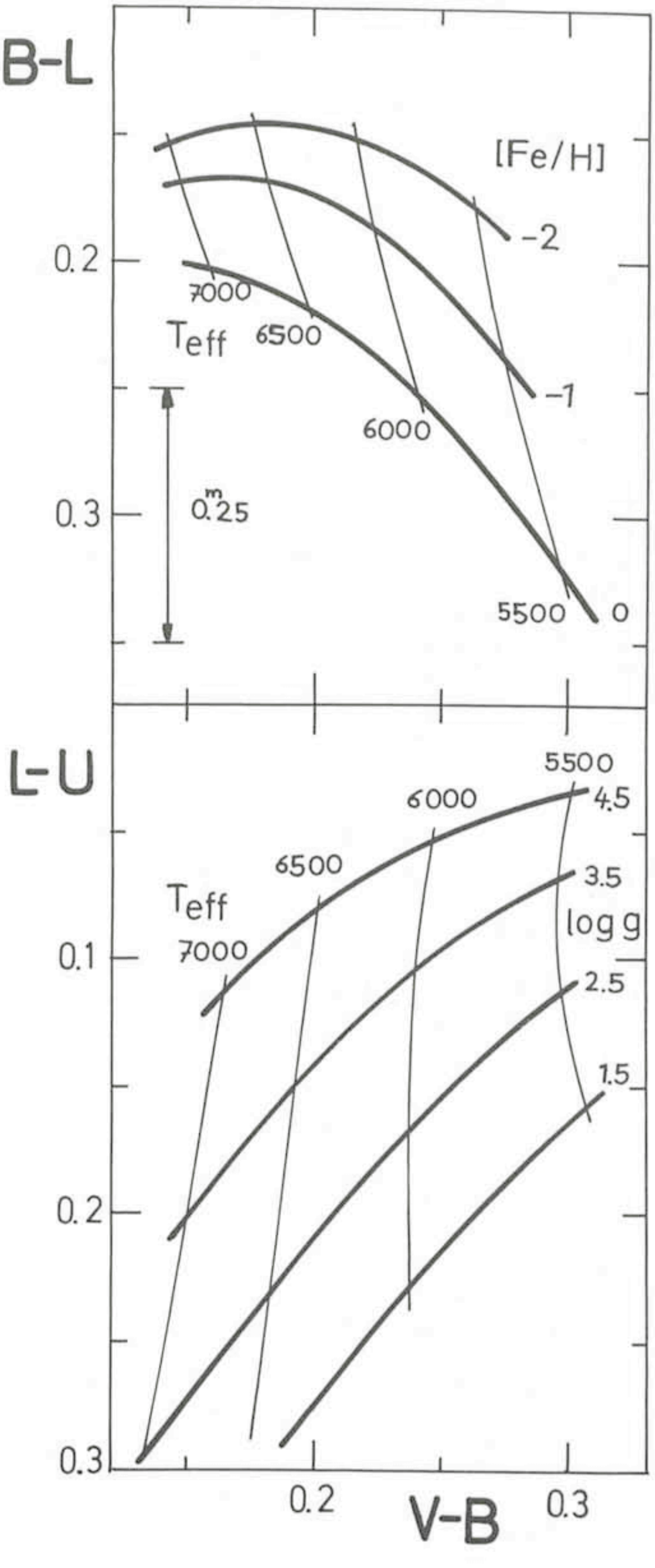

Fig. 1: *These two diagrams show how the effects of metallicity and gravity can be separated with VBLUW photometry. The upper (V-B)-(B-L) diagram is almost gravity-independent and gives the stellar metallicity [Fe/H]. The lower (V-B)-(L-U) diagram is almost insensitive to metal line strengths and can therefore be used to determine temperature and gravity independently of [Fe/H]. The drawn lines correspond to theoretical colours calculated from Kurucz models. Note that all VBLUW diagrams are in log (intensity), so multiply by 2.5 to get magnitudes.* ▶

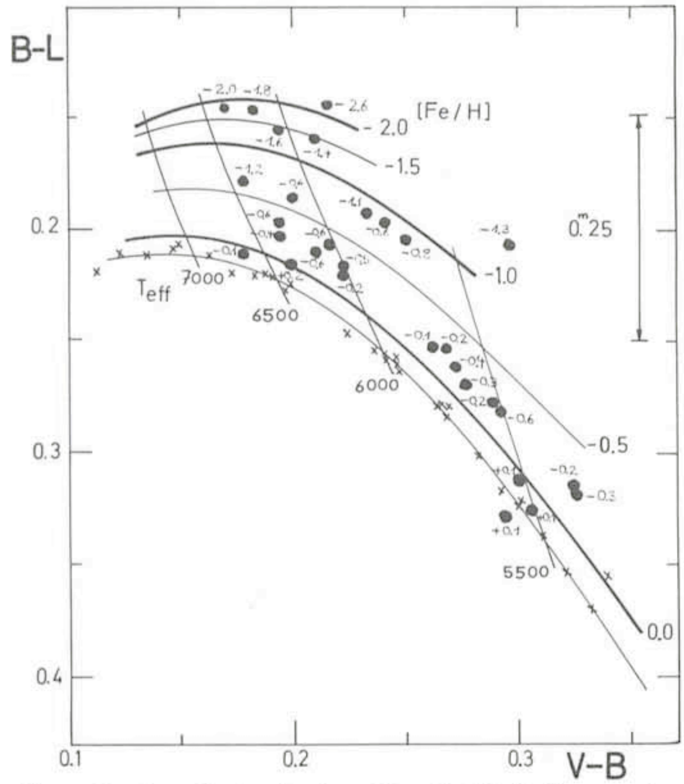

Fig. 2: *Semi-empirical calibration of the (V-B)-(B-L) diagram using stars with spectroscopically known metallicities, temperatures and gravities (full circles with corresponding [Fe/H] values). Hyades main-sequence stars are indicated by crosses.*

metallicity (Fig. 2). The notation [Fe/H] is a logarithmic measure of the stellar iron abundance relative to the sun: eg. [Fe/H] = −1 means that the iron abundance is 10 % of the solar value. We used the location of the main-sequence stars of the Hyades as our reference line, adopting [Fe/H] = + 0.15 for this cluster. The resulting T_{eff} – [Fe/H] grid allows us to determine metallicities quite accurately. It is based on data for dwarf stars, but it does not depend strongly on gravity differences.

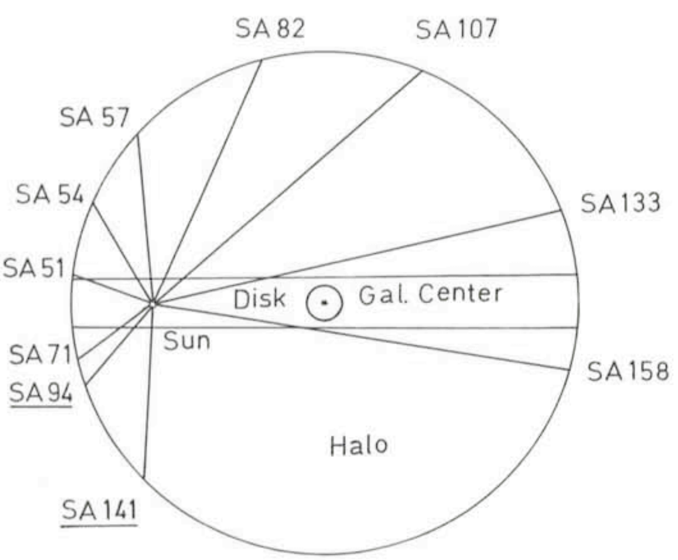

Fig. 3: *The Selected Area fields of the Basel halo programme. They are close to a meridional plane perpendicular to the galactic plane containing the galactic centre and the sun. The fields where Walraven photometry has been carried out are SA 141 and SA 94. There size is about two square degrees.*

The location of main-sequence stars (log g ≈ 4.5) in the gravity-sensitive (V-B)-(L-U) diagram agrees reasonably well with the predicted theoretical colours and the same holds for more evolved stars with log g in the range between 1.5 and 3.5. Although the calibration of this diagram is still in progress, we are able to separate main-sequence stars from subgiants and giants in this way.

Metal Abundances of F and G-type Stars in SA141 and SA94

The sample was selected from the existing Basel photographic RGU photometry in the Selected Areas No. 141 and No. 94. The field SA141 points towards the South Galactic Pole and SA94 has a latitude of −49° in the direction of the anticentre (Fig. 3). The criteria for selecting our programme stars were purely photometric: All stars with (G-R) < 1ᵐ15 (spectral type earlier than about G7) were measured in each field of 1°.5 x 1°.5 size. Until now we have analysed 90 stars in SA141 brighter than V = 14ᵐ5 and about 30 stars in SA94 brighter than V = 12ᵐ7. More data in both fields were obtained

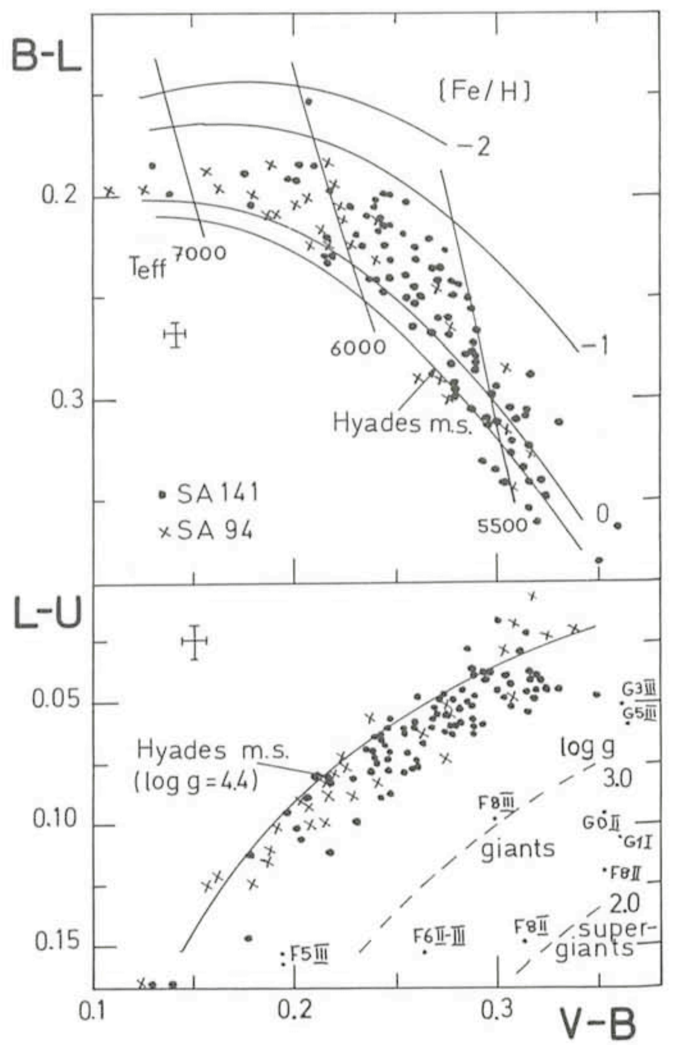

Fig. 4: *Walraven photometry of our programme stars. The error bars indicate typical standard deviations. Fig. 4a: The distribution of the stars in the (V-B)-(B-L) diagram indicates that their metallicities vary between [Fe/H] = 0.0 and −1.0. Fig. 4b: In the gravity-sensitive (V-B)-(L-U) diagram the distribution of the stars is quite narrow (around log g = 4.2 ± 0.3) which suggests that most of them are dwarfs. Indicated is also the location of typical nearby giants and supergiants in this diagram.*

in December 1983, but these measurements are not yet fully reduced.

Using the calibrated (V-B)-(B-L) diagram, we determined the parameters T_{eff} and [Fe/H] for each programme star (Fig. 4a). For this purpose we assumed that interstellar reddening in the South Galactic Pole field SA141 can be neglected, and we adopted a constant foreground reddening of $E(B-V)_J = 0^m.05$ for SA94. The distribution of the stars in Fig. 4a indicates that their metallicities are in the range $-1.0 \leq$ [Fe/H] ≤ 0.0. In the gravity-sensitive (V-B)-(L-U) diagram (Fig. 4b) the programme stars populate a narrow range suggesting that the gravities are around log g = 4.2 ± 0.3. This means that our stars are probably all dwarfs with only a few possible subgiants.

An empirical absolute magnitude calibration was derived by using the data of Cayrel de Strobel and Bentolila (1983, *Astronomy and Astrophysics* **119,** 1). From their [Fe/H] catalogue we took all stars with known distances, and with the same range in T_{eff}, [Fe/H] and log g as our programme stars, to construct an empirical absolute magnitude-temperature relation. With this relation we determined the distances of the programme stars in SA141 and SA94.

In Fig. 5 the metallicities are plotted as a function of vertical distance z above the plane. The z values of the programme stars observed until now vary from almost zero up to z = 1,000 pc with a few stars beyond this. The diagram clearly shows a correlation between distance and metallicity in the sense that stars further away from the plane are systematically metal-deficient. For example, stars at z = 750 pc have a mean metallicity of [Fe/H] = −0.7 which is five times more metal-weak than the sun.

Our calibrations are in many respects preliminary and improvements are expected for the near future. Measurements of many more nearby metal-deficient stars analysed spectroscopically are now a vailable in the Walraven system so that the calibration of the (V-B)-(B-L) diagram can be put on a broader observational basis. Furthermore, for the determination of the absolute magnitudes we disregarded such effects as metallicity or age differences between the stars and used a mean M_V-T_{eff} relation. A more detailed procedure is clearly needed.

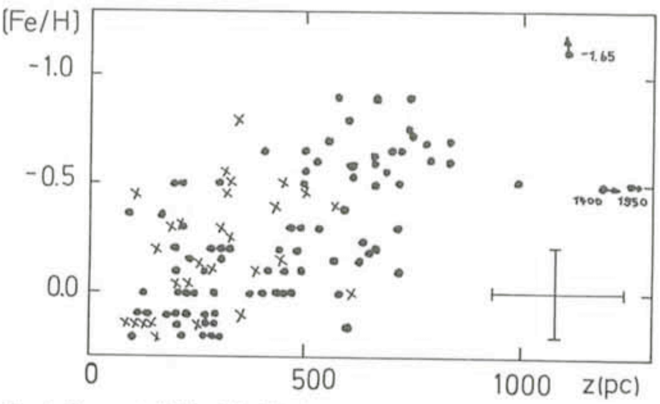

Fig. 5: *The metallicities [Fe/H] of our programme stars as a function of vertical distance z above the galactic plane. The diagram clearly shows that the metal content of the stars decreases rapidly as we go away from the disk into the halo.*

Nevertheless, our preliminary results are in reasonable agreement with previous determinations of abundances in the direction of the galactic poles. The earlier work by Blaauw and collaborators indicated that the metallicity drops to about [Fe/H] = −0.5 at z = 500 pc which compares well with [Fe/H] = −0.4 estimated from our Fig. 5. Our results are also consistent with the metallicities of halo stars derived from the photographic RGU colours (Trefzger, 1981, *Astronomy and Astrophysics* **95,** 184). Our data can be used to check the predicted metallicity distributions at different z heights derived by Sandage (1981, *Astronomical Journal* **86,** 1643) from the W velocity components of nearby subdwarfs and several kinematic models.

We hope to get our photometry complete in both fields down to the limiting magnitude of the telescope ($V = 14^m.7$). In SA141 this limit has been reached already, but more observations are needed in SA94. Eventually we will try to extend the observations to other fields as well.

One-mm Observations of BL Lacertae Objects

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Introduction

Forty years have elapsed since C.K. Seyfert in 1943 observed galaxies with strong activity in their centres. Twenty years later a new class of extragalactic objects entered the scene: the quasi-stellar objects (QSOs or quasars) representing the most extreme examples of energy output in the Universe. Today there is growing evidence for a continuity of properties among these "active galactic nuclei" (AGN) and it is now generally agreed that what is happening in the centres of these objects is qualitatively the same. This large group of objects also includes other active galaxies, namely radio galaxies with strong emission lines and *BL Lacertae objects.* The latter are named after their prototype lying in the constellation Lacertae (the lizard) and are abbreviated as BL Lac objects. The aim of this article is to describe and interpret some results obtained from 1-mm observations of these BL Lac objects.

Observations in this part of the spectrum are challenging. The Earth's atmosphere is almost opaque to much of the radiation, mainly due to the water vapour content of the atmosphere. To overcome this difficulty observations must be carried out on high, dry mountain sites. In the absence of suitable radio telescopes (surface accuracies of ~ 50 μm are needed), we had to use large optical telescopes, in particular the ESO 3.6 m telescope on La Silla and the 6 m SAO telescope at Zelenchukskaja in the Caucasus.

What Are BL Lacs?

The properties of BL Lacs can be summarized as follows:

- Nearly all known BL Lac objects have been discovered because they are radio sources.
- Their radio spectra ($S_\nu \propto \nu^\alpha$) are flat and often inverted, i.a. $\alpha \geq 0$.