and the GHRS. In addition to lines from the Galactic halo and at the redshift of the Virgo cluster, there are nearly an order of magnitude more Lyman-α systems than expected from the behaviour of the forest above $z \sim 2$. Indeed, with a velocity resolution of 3.5 km/s, the GHRS is proving to be a superb interstellar medium machine with lines down to mÅ equivalent width being seen in the UV spectra of bright stars (ξ Per, β Pic and Capella). As an interesting aside, atmospheric OI lines can be seen and used to provide an accurate internal wavelength calibration. Studies of exotic elements in χ Lup and chromospheric features in α Tau were presented. The current sophistication in the modelling of the atmospheres and winds of hot stars was demonstrated by the successful fitting of the P Cyg profiles in Melnick 42, a 100 $M_\odot$ in the 30 Dor nebula.

Within the Solar System, the HST provides the opportunity to carry out extensive planetary campaigns, something not afforded by the fly-by missions. Mars can be studied for long periods with a surface resolution similar to or exceeding that obtained under exceptional circumstances from the ground only at opposition. The atmospheres of Jupiter and Saturn can be seen at a resolution similar to that of the Voyager approach sequences and, of course, the ultraviolet part of the spectrum is available for the first time.

Some of the data discussed at the workshop are already in the public domain and available from the ST-ECF archive in Garching. All of the science verification data will become public soon after the end of the SV phase later this summer.

The "Discovery" of Paranal

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Introduction

Early morning on April 10, 1983 an expedition consisting of Mr. Bachmann, Ms. Demierre, Dr. Muller, Mr. Schuster, Mr. Torres and myself left La Silla to explore some northern sites in Chile. The next day we visited the Paranal area for a first inspection. After subsequent discussions with the *Intendente* in Antofagasta and a visit to the areas of S. Pedro de Atacama, we returned by plane to have another look at Paranal and its surroundings. Soon thereafter, under the leadership of Dr. Ardeberg, an observing station was set up at Paranal that provided the data based on which some seven years later the decision could be taken to locate the VLT there. It may be of some interest to describe the reasons why Paranal could be considered a promising site so early on.

At the beginning of the eighties plans for the VLT were still in a preliminary stage. It was clear, however, that infrared observations would constitute an important part of the raison d'être of the VLT; the choice of 8-m unit telescopes was, in part, dictated by the wish not to be diffraction limited at 20 microns wavelength. Since infrared observations from the ground are hindered mainly by water vapour in the earth's atmosphere, a very dry site was needed. Water vapour will absorb wherever it is located, and what matters is therefore not the local humidity but the integrated amount of water vapour in the atmosphere above the site. It is usually expressed in mm of precipitable water – the amount of rain that would fall if all the water vapour rained out. Sites with less than 1 mm of H_2O are comparatively very good sites for IR observations, sites with more than 3 mm rather poor. The local humidity has only a limited relation to the integrated amount of water vapour. If it is locally very humid, the integrated

Figure 1: *The first ESO expedition to Paranal (from left to right: H.-E. Schuster, A. Muller, G. Bachmann, and the author; photograph Ms. U. Demierre).*

[1]Professor Lodewijk Woltjer was Director General of ESO from 1975 to 1987.

Figure 2: *Paranal stands isolated and has the shape of a cone, two features of vital importance for the air flow over and around the mountain.*

amount of H_2O is generally high, but above some dry sites there may be a more humid layer higher up. Thus, in looking for high-quality sites, one should begin by looking for very dry sites, but subsequently measure the integrated amount of H_2O; this may be done with an instrument that monitors the intensity of the infrared emission bands emitted by water molecules. Two such instruments were bought by ESO from Kitt Peak National Observatory about a decade ago.

Low water vapour content was, of course, not the only condition. The VLT site should also meet the traditional criteria of low cloudiness and low atmospheric turbulence.

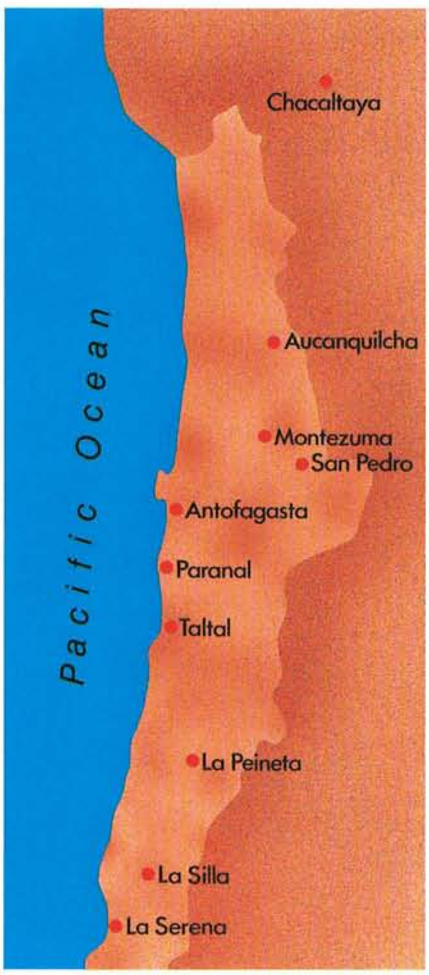

Figure 3: *Identification of sites in Chile.*

What was Known in 1983?

The site surveys conducted by AURA, ESO and CARSO had indicated that some of the world's best sites were located in Chile, inland from La Serena and somewhat further north. Some studies had also been conducted at La Peineta, east of Copiapó, where the number of clear nights was somewhat larger than at Tololo/La Silla, but with stronger winds. There was some reluctance to go so far north, because it was believed that the Magellanic Clouds would be the most important objects for study; even at La Silla the Small Cloud would be at best 43° from the zenith, and further north the situation would be still less favourable. In the meantime it has become clear that, though important, the Magellanic Clouds account for only a small percentage of the total observing time at the large telescopes, because the southern sky is so rich in other interesting objects. By 1980, some water vapour measurements had been made at La Silla and at Tololo which indicated that these were fair, but certainly not excellent infrared sites.

Long before these site surveys were made, the Smithsonian Institution had operated the "Montezuma station" (2700 m) just south of Calama in northern Chile. C.G. Abbot who for almost fifty years directed the Smithsonian Astrophysical Observatory was engaged in a programme to measure the "solar constant", the intensity of the solar radiation and its possible variations with time. Since an important part of the solar radiation is emitted in the near infrared, searches were made for the driest spots on earth (1). The best place at moderate altitude was found to be Mt. St. Katherine in the Sinaï desert, where from 1934 to 1937 observations were made. Finally "war, excessive isolation and the tendency to intestinal sickness there" caused the end of the activities. In the southern hemisphere, South West Africa (now Namibia) was rather disappointing, but more favourable conditions were found in northern Chile. Observations of the sun were obtained at Montezuma during some two decades beginning in 1923. Abbot found that the winter water vapour content averaged below 3 mm, with many days below 1 mm. Unfortunately the variations of the "solar constant" found by Abbot appear to have been spurious since satellite data indicate much smaller variations. Although the precise calibration of the water vapour measurements is perhaps uncertain, it is clear that Montezuma is an exceptionally dry site, as was amply confirmed by

Ardeberg's measurements in northern Chile half a century later. It is interesting to note also that C.P. Butler of the Smithsonian observed in 1935 for a few days at Mt. Aucanquilcha, nearly 6000 m, and found the solar radiation to be stronger there than anywhere else on the earth's surface (2). The same mountain was later included in the ESO site survey by Ardeberg.

Afterwards, when it had become clear that high-precision measurements of the "solar constant" are unlikely to be made from the surface of the earth, interest in dry sites diminished until the advent of IR astronomy led to its revival. During 1975–1976, J.W. Warner made a 12-month series of measurements at Chacaltaya (3) a cosmic-ray research station at 5360 m near La Paz. Monthly averages of H_2O were mainly in the range 2–3 mm, perhaps somewhat disappointing for such a high site. The tentative conclusions that could be drawn from all these data were that very dry sites might be found well to the north of La Silla, but that going too far to the north into Peru was likely to be counterproductive.

Precipitation has some relation to humidity. Here the situation was clear: to the north of La Silla rainfall declines to very low values, while to the east in the higher Andes and to the far north (Chacaltaya) it increases. Rainfall has an interesting temporal pattern in Chile: at La Silla and Copiapó it rains in winter, but in the far north the little rain that falls comes in summer, a pattern continuing into Peru. This would tend to suggest that the La Silla precipitation comes from disturbances to the south, while disturbances to the north cause the precipitation in the very north of Chile. It might then perhaps be expected that the atmosphere would be relatively undisturbed in the region in between. In the desert, however, the strong daily heating would still cause much turbulence, except close to the coast, where it might be suppressed by the cool breeze from the ocean. In general, island or coastal sites seem to have more favourable conditions for astronomical "seeing" than sites further inland.

Finally, cloudiness is an important parameter. It was known that cloudiness diminished going from La Silla to Copiapó. Day-time cloudiness at Montezuma appeared to be of the order of 30 %, while at Chacaltaya it was already substantially higher. Everyone who has visited La Silla in summer will have seen the towering clouds above the mountains to the east, some of which must still be present during part of the night. A study of satellite data by Ardeberg confirmed these findings: cloudiness is lowest in the northern Chilean deserts, but increases in Peru (4).

From all these rather fragmentary data it seemed that it would be worthwhile to look for high coastal sites substantially to the north of La Silla but within Chile. Some evening looking at the map of Chile, I realized that there was only one place with mountains in excess of 2500 m coming close to the coast, namely the area around Paranal. The only mention I have found of this area in the astronomical literature is by J. Stock, who made the Tololo site surveys (5): "There are a number of mountains of sufficient elevation south of the town of Antofagasta and very close to the coast. The abrupt rise from the Pacific Ocean on one side, and a large flat plain, more than 1000 m lower, on the other side, give these mountains rather special conditions. High stability, that is, good seeing, is expected for night-time conditions. Furthermore, the extremely low humidity makes this area very suitable for astronomical work in the infrared. Since this area is absolutely arid, water supply for an observatory will be difficult and costly. Underground currents may exist, but most likely at a prohibitive distance and depth." It is curious to note this preoccupation with water, which also played such an important role in ESO's site selection. The Chileans had discovered long before that water can be transported. In any case, it seemed worthwhile to have a look at the Paranal area.

To Paranal

On maps of northern Chile, many roads are indicated. Not all of them exist and even if they do they need not be passable. The road passing a few km east of Paranal being the old Panamericana, we at least had a reasonable confidence that we could get there. Accordingly we first went to Taltal and spent the night at the *hosteria* there. Food was difficult to obtain, but fortunately the owner – a retired seaman and part-time gold miner – was barbecuing a pig for some friends. The next morning we set out along the coast under a somber cloudy sky. Fifty km further north at Paposo, the old frontier town (with Bolivia), we turned inland, and a steep climb began. We came into the clouds at about a thousand metres altitude. Suddenly, after going up a bit further, the clouds gave way to a spectacularly clear, deep blue sky. At La Silla, when one looks near the sun, the blue usually turns milky because of scattering of the sunlight, but here it remained unchanged until as close to the sun as one dared to look. At the same time, the last trace of vegetation disappeared as we entered the most absolute desert we had ever seen. Not a trace of life was there: no birds, no insects, nothing at all. Nor did we meet any car on the more than 100 km road that brought us through the Paranal area. To the east, the Vicuña McKenna mountains shimmered in the heat of the sun, but towards the ocean the atmosphere looked more stable. Our vehicles were insufficient to actually go up to Paranal, and so we moved on to Antofagasta. Our first view, however, had already been sufficiently impressive that we paid a visit to the *Intendente* of the province to obtain his agreement for some ESO activities there. At the time this was particularly necessary, since the mounting of strange equipment

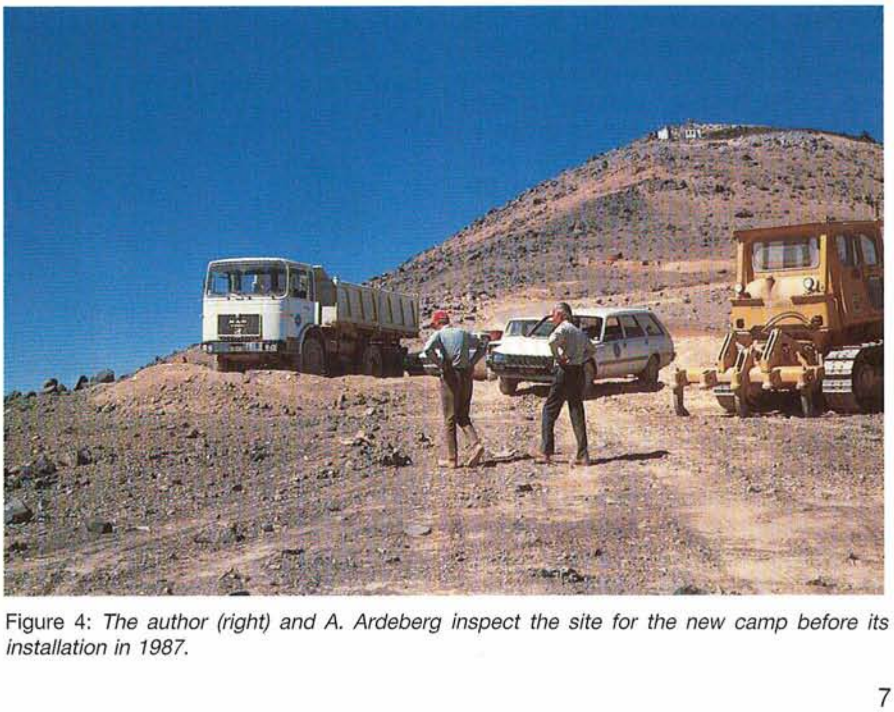

Figure 4: *The author (right) and A. Ardeberg inspect the site for the new camp before its installation in 1987.*

close to the coast in the middle of nowhere by some foreigners could easily have been misinterpreted. Subsequently, we passed by Montezuma and visited S. Pedro de Atacama to see the area further to the east. It did not seem easy to find there fully free standing mountains with heights of less than 4000 m – about the highest possible for normal work without special provisions for oxygen.

We planned to fly back from S. Pedro via Paranal, and then over some inland mountains near the Salar de Punta Negra. Accordingly a plane was chartered which landed on the airstrip of S. Pedro, but it got stuck in the sand. All of us had to push to get the plane to a harder part of the surface, and when finally we were taking off, not all passengers looked very happy. Since the pilot had deliberately taken only a small amount of fuel, the plane managed to take to the air and half an hour later we landed at Antofagasta. The subsequent flight over Paranal was interesting. Flying over the narrow strip of mountains between the old Panamericana and the ocean, the atmosphere was absolutely stable, but as soon as we came east of the road, strong turbulence was felt. The view was spectacular with the blue ocean and white low clouds on one side and the steep cliffs and absolute desert on the other. After circling Paranal a few times, we continued the flight southward, still more convinced that measurements should begin there as soon as possible. A few months later Dr. Ardeberg had the observing station installed and manned by Mr. Gomez and son, who measured the H_2O content every two hours around the clock and, of course, also made observations of cloudiness and other meteorological parameters.

A site may be very dry and the sky very transparent and free of clouds; however, if the "seeing" conditions are not very good, it is all in vain. Fortunately, the seeing monitor installed by Dr. Sarazin some years later showed that also as far as atmospheric turbulence is concerned, Paranal is excellent, in fact better than La Silla.

The Future

Paranal has now been chosen as the site for the VLT. This gives a unique chance to rationally construct a new observatory which may look rather different from La Silla with a smaller resident staff and a more intensive direct communication to Europe. It will be particularly important to place at and around Paranal only telescopes and instruments that use the essential characteristics of the site, and especially during the installation phase of the VLT to avoid the plethora of small telescopes which have made the La Silla operation rather heavy.

Paranal is probably the observatory site with the lowest cloudiness in the world and also among the best in "seeing" and water vapour content. Are there still better sites to be discovered? Some astronomers think that the central area of the antarctic plateau – closer to the pole than the region of strong winds – may be particularly suitable because of its very low humidity. Since the sun is never far below the horizon, the number of hours of darkness is rather small and the site seems appropriate only for IR and sub-mm observations. The cost per hour of observation would be very high, and it is clear that only special-purpose instruments could justify this cost. On a longer time scale the lunar base currently under study may offer unique possibilities for astronomy at all wavelengths. None of this, however, is likely to endanger the role of Paranal as one of the world's leading observatories for the next half century.

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ESO Awards VLT Contracts to Dutch and Danish Firms

The decision to place the world's largest telescope, the ESO 16-metre equivalent Very Large Telescope (VLT) on the Paranal mountain in the Chilean Atacama desert, taken by the ESO Council on 4 December 1990, has now been followed up by an important next step. During a small ceremony on April 26, 1991 at the ESO Headquarters in Garching, two major contracts were signed which will together define the future shape of the VLT Observatory and its infrastructure.

Following a call for tenders which was responded to by a large number of engineering companies in the ESO member countries, ESO awarded contracts to INTERBETON of The Hague, the Netherlands, and COWIconsult of Copenhagen, Denmark. The contracts were signed by Mr. A.J.M. Boersma, Area Director (INTERBETON), and Mr. K. Østergaard Hansen, Executive Director (COWIconsult), and Professor H. van der Laan, Director General of ESO.

INTERBETON will carry out the levelling and landscaping of the Paranal mountain, so that it can accommodate the entire array of 8-metre and auxiliary telescopes as well as associated buildings that together make up the VLT Observatory. About 23 metres will be cut off the Paranal peak by blasting and ripping, leaving a flat area of about 20,000 m^2 at 2640 m altitude. In July

From left to right: Mr. K. Østergaard Hansen, Executive Director of COWIconsult; Prof. H.v.d. Laan, Director General of ESO; Mr. A.J.M. Boersma, Area Director of INTERBETON.