purple *Pata de Guanaco* (Fig. 11), covered large extensions of fields alternating with the yellow *Violas del Campo* (Fig. 12) and the *Rositas* (Fig. 8). This is the time when photographic cameras get inspired and the telescopes emerge from unusual green surroundings. The curious visitor will spot the *Terciopelos* (Fig. 9) whose colours range from yellow-orange to dark brown. The velvet flowers make a point of growing on bare ground where other plants cannot compete.

Of the two native trees which grow in our region the *Chañar* (Fig. 3) is the most spectacular one during the flowering season. It shrouds itself in orange blossoms and attracts thousands of bees. The tree has lent its name to hundreds of places in Chile where the villages of Chañar and Chañarcillo compete in numbers with the Algarrobos and Algarrobillos. The elegant and thorny *Algarrobo* tree (Fig. 6) populates the quebradas and has invaded Mr. Schumann's garden located five hundred metres below the mountain top. It is moderate in water consumption and will eventually outnumber the ever thirsty poplars and eucalipti, thriving on our waste waters.

On the road to La Silla the flower festival is led by the *Encelias* which Chileans identify with the lovely name of the *Coronilla del fraile* (the friar's crown).

On the mountain itself the *Soldadillos* (little soldiers – Fig. 7) line up. They are the mountain cousins of the garden Capucins. Several of those wild species *(tropaeolums)* exist in Chile and the coastal slopes harbour a magnificent three-colour version.

The white crosspetal *Schizopetalon* deserves a special mention as it is adapted to our activities. It opens up at sunset and sends its honey smell through the night before closing in the morning.

Many more wild flowers grow on our slopes: the candid *Mariposas blancas* (Fig 10), *Adesmias, Senecios, Malvillas* and magnificent *Alstromerias.*

Dr. Grenon, our walking encyclopedia, has identified over 150 endemic species in our surroundings. Who said La Silla is a desert . . .?

New Aspects of the Binary Planet Pluto-Charon

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Introduction

Never since the discovery of Pluto in 1930 has our knowledge about this tiny far-out planet improved so rapidly as during the past five years. The coincidence of two rare opportunities that occur together only once every 250 years kept astronomers around the world busy to solve the puzzle of Pluto and its satellite Charon.

In 1987/88, the plane of Charon's highly inclined orbit around Pluto swept over the inner solar system. This gave rise to a series of mutual occultations and transits of the planetary disks that were observable from Earth between 1985 and 1990 (cf. Fig. 1). Nearly at the same time, on September 5, 1989, Pluto reached the perihelion of its eccentric orbit around the Sun which placed the binary system within range for photometry with medium-sized telescopes.

The shapes and the timings of the mutual eclipse light curves not only reflect the geometry of the system (which had been scarcely known before) but also provide information about the gross albedo distribution on Pluto and Charon.

In an earlier issue of the *Messenger* (Pakull and Reinsch, 1986), we reported the analysis of the first eclipse light curves observed in 1985 and 1986 which revealed that the diameter of Pluto was much smaller than previously believed.

Thanks to generous allocation of ESO time we were able to continue our study of the mutual eclipse light curves.

Eclipse Observations

As the aspect of Charon's orbit around Pluto as seen from Earth varies with time, different areas on Pluto are occulted during the eclipses (Fig. 2). The eclipse series started in early 1985 with occultations of the north polar region on Pluto. While in 1986 and 1987 large fractions of the northern hemisphere were covered as Charon crossed in front of Pluto, Pluto's southern hemisphere was involved in the eclipses throughout the rest of the series until 1990.

To exploit the full information provided by the mutual eclipses it was therefore necessary to spread observations over the whole period of eclipse phenomena. Due to the fact that the binary system is in a bound rotation it is, however, only possible to derive the gross albedo distribution on one hemisphere of Pluto and Charon, respectively.

From 1985 to 1990 we successfully observed six transits of Charon in front of Pluto (inferior events) and eight occultations of Charon by Pluto (superior events). The photometry was obtained with the ESO/MPI 2.2-m and the Danish 1.5-m telescope, respectively, using CCD direct imaging techniques which allow high-precision differential photometry even if sky conditions are not strictly photometric. Our data base was supplemented by published light curves of eleven further events (Binzel et al., 1985; Tholen et al., 1987 b; Binzel, 1988, Tholen and Buie, 1988; Tholen and Hubbard, 1988).

While the first grazing eclipse light curves could be analysed using models for eclipsing binary stars, more sophisticated algorithms were required as the eclipse series continued. The light curves were then complicated by shadow transits which occurred displaced in time relative to the eclipse events (Fig. 3).

The analytical model developed by Dunbar and Tedesco (1986) to derive the physical parameters of a binary

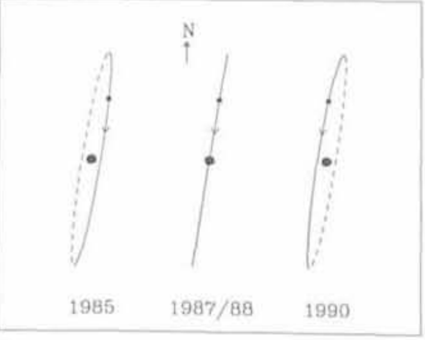

Figure 1: *Apparent view of Charon's 6.4-day orbit around Pluto between 1985 and 1990.*

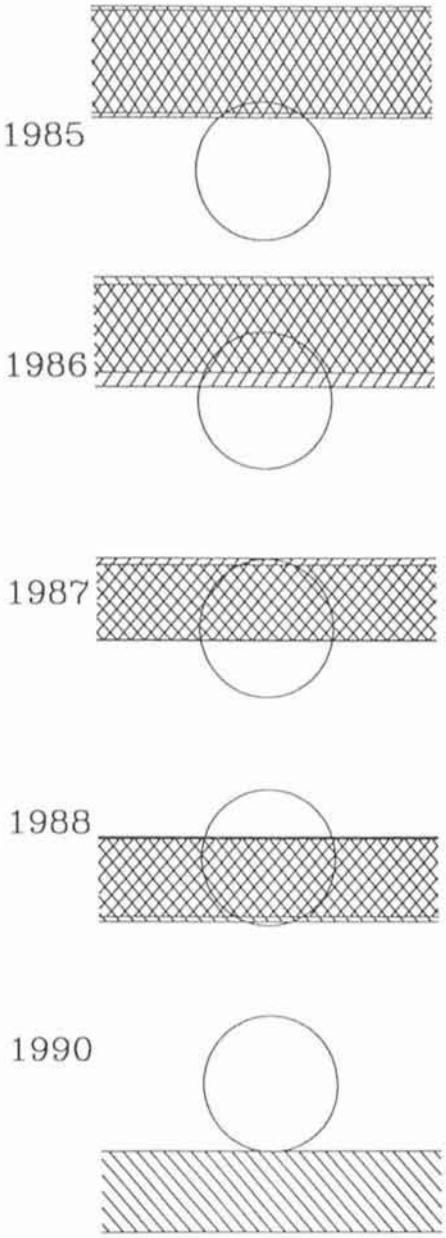

Figure 2: *Projected paths of Charon and its shadow across Pluto. The northern and southern extremes of the observed transits are displayed for each year.*

Table 1: *Physical parameters and orbital elements of the Pluto-Charon system derived from the least-squares fit of our analytical model.*

	Pluto	Charon
Radius r [km]	1151 ± 20	591 ± 11
Mean density ϱ [g/cm^3]	2.032 ± 0.040	
Mass m [10^{22} kg]	1.47 ± 0.07	
Absolute brightness V (1,0)	−0.648 ± 0.010	1.350 ± 0.010
Mean geometric albedo p_v	0.618 ± 0.020	0.372 ± 0.012
Apparent inclination (17.4.87) i [degrees]	90.710 ± 0.032	
Sidereal orbital period P [days]	6.387244 ± 0.000007	

planet from eclipse light curves was adapted to our problem. In a first-order approach, we assumed a constant albedo for Pluto and Charon, respectively. The light curves obtained with this model showed that the albedos of the northern and southern hemisphere were significantly different. Therefore, we modified our first-order model introducing separate parameters for the albedos of the northern and southern hemisphere.

We performed a multi-parameter least-squares fit to our data using the analytical model light curves. Adopting the orbital radius of 19640 ± 320 km for Charon determined by Buie and Tholen (1990) the best solution of our fit yielded the improved physical parameters of the system given in Table 1.

The radii of (1151 ± 20) km derived for Pluto and (591 ± 11) km for Charon are in good agreement with our earlier results (Pakull and Reinsch, 1986). They confirm that the radii are significantly lower than those found by previous observers using speckle interferometric techniques. The error uncertainties could be reduced by more than a factor of 3, and the slight discrepancies in the results of different eclipse observers could be solved (cf. Dunbar and Tedesco, 1986; Tholen et al., 1987 a; Reinsch and Pakull, 1987; Tholen and Buie, 1990).

A comparison of our best-fitting model with the observed light curves reveals that systematic differences still remain. These must be attributed to local deviations from the assumed constant albedo of Charon and of Pluto's northern and southern hemispheres (cf. Fig. 4).

Based on our improved physical parameters of the system, we chose a numerical approach to derive individual albedo values for a grid of surface areas on Pluto. The boundaries of the surface elements were selected to match in latitude with the five groups of eclipse paths and to suit time-resolution of our data (longitudinal strips).

We found that the significant surface structures needed to fit the photometry are already described by a grid of 17 surface elements. The albedo distribution derived is independent of the particular method used to define the grid (longitudinal or rectangular division, cf. Fig. 5).

Our albedo map reveals that areas of high contrast must coexist on the Charon-facing hemisphere of Pluto. The highest contrast found was that between the two polar caps. While the south polar region appears to be the brightest area on the planet, we found that the north polar region has the lowest albedo. This is a surprising result because the south polar region is the one that has been exposed to perma-

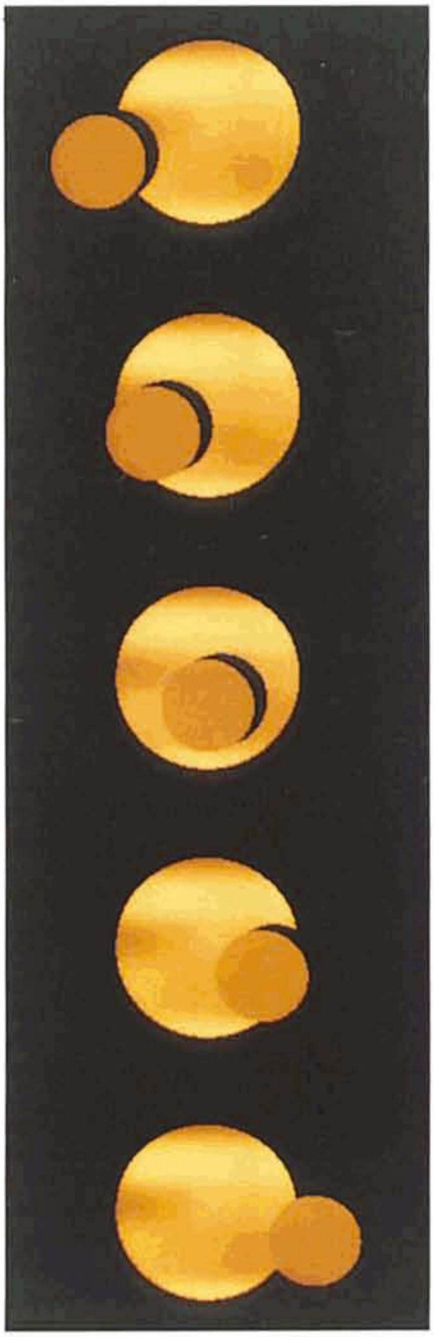

Figure 3: *Series of reconstructed images showing the transit of Charon and its shadow across Pluto on May 1, 1988.*

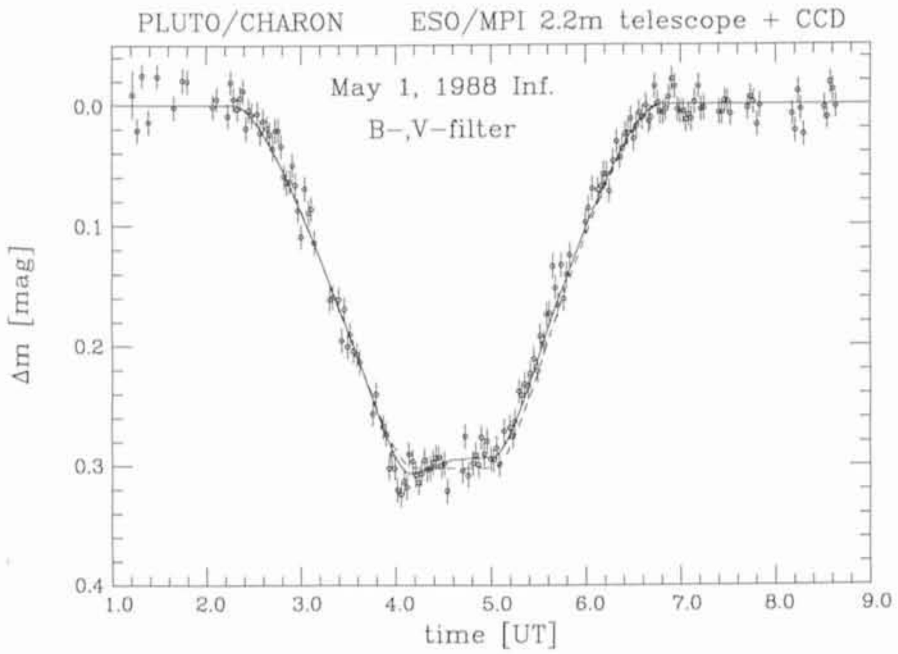

Figure 4: *Example of an eclipse light curve observed on May 1, 1988 with the ESO/MPI 2.2-m telescope (combination of B- and V-filter measurements). The two lines superimposed on the data represent our purely geometrical model (dashed line) and our albedo model (continuous line), respectively.*

nent irradiation from the Sun as Pluto approached perihelion.

From simultaneous observations in different colour bands we found no systematic colour variations of the surface structures on Pluto. The eclipse depths were, however, detected to be colour dependent for occultations of Charon. In this case the eclipses observed in the B-filter were slightly deeper than those observed in the V-filter.

The Rotational Light Curve of Pluto

The variation of Pluto's visual brightness with a period of 6.4 days (cf. Fig. 6) was first detected by Walker and Hardie (1955) and has been interpreted as the rotational period of the planet. This rotational light curve contains independent information about the albedo distribution on Pluto.

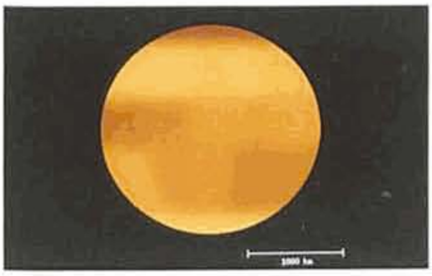

Figure 5: *Albedo map of Pluto reconstructed from a grid of 17 surface elements. The albedo distribution has been smoothed to reproduce the spatial resolution obtained. The north pole is to the top.*

It has been noted that the "absolute" mean brightness V(1,0) of the planet has increased by 0.3 mag since 1954. At the same time, the amplitude of the rotational light variation has become significantly larger.

Attempts to model the albedo distribution on Pluto have already been published using the information provided by this secular variation of the rotational light curve (Marcialis, 1988; Buie and Tholen, 1989). Buie and Tholen derived two distinct configurations of dark and bright spots on Pluto that fit the out-of-eclipse photometry equally well (models 'MAX' and 'SHELF').

Whereas these models assume that the surface structures have not changed during the past 35 years, there is some evidence from the detection of a substantial atmosphere of Pluto (Elliot et al., 1989) that a cyclic methane sublimation and freeze-out may occur during Pluto's eccentric orbit (Stern et al., 1988). This would be an alternative explanation of the rotational light curve changes and implies that the albedo distribution on Pluto could be variable on a time scale ≳10 years.

A straightforward method to derive the albedo distribution on Pluto has become available during recent years. As we have viewed the equator of Pluto nearly edge-on around 1987/88 a deconvolution of the rotational light curve yields the instantaneous longitudinal albedo distribution on Pluto without requiring further assumptions.

Besides the eclipse observations we have, therefore, obtained absolute photometry of Pluto's rotational light curve between 1982 and 1990 using the Walraven photometer attached to the Dutch 0.91-m telescope and the single-channel photometer at the ESO 1-m telescope. The observations have been reduced to the "absolute" brightness V(1,0) corresponding to unit distances Pluto-Sun and Pluto-Earth and to a phase angle of 0° (cf. Fig. 6).

From information theory it is known that the deconvolution of a light curve is numerically instable if the low frequency intensity variations are largely contaminated by statistical fluctuations. The low and high frequencies can, however, be separated by computing the Fourier transformation of our light curve. We found that our original light curve is already well described by its first two Fourier components within the statistical errors of the data (see Fig. 6). We have deconvolved this analytical light curve to derive the longitudinal albedo variation on Pluto (Fig. 7). The albedo distribution obtained shows a double peaked structure. The maximum of the latitude averaged albedo is attributed to the longitudinal strip which faces towards Earth at rotational phase 0.65. The minimum albedo corresponds to the region being in front at phase 0.95.

While the features of our longitudinal albedo distribution resemble most of those implied by the 'SHELF' model (e.g. maximum and minimum albedo), the existence of a second maximum at rotational phase 0.2 is neither supported by the 'SHELF' model nor by our eclipse map.

We found no colour dependence of the rotational light curve and, consequently, of the longitudinal albedo distribution. The colour difference for the Pluto-Charon system is $(B-V)_{Pl/Ch} = 0.846 \pm 0.010$ and does not vary with the rotational phase. From the depths of the superior events where Charon is totally eclipsed we computed the colour differences for Pluto $(B-V)_{Pl} = 0.871 \pm 0.014$ and for Charon $(B-V)_{Ch} = 0.701 \pm 0.014$ which show that Pluto is redder than Charon.

Discussion

Our finding of a dark north polar cap on Pluto is in contrast with the bright polar caps required by the models of Marcialis (1988) and Buie and Tholen (1989) to account for the secular variation of Pluto's rotational light curve. The existence of a dark polar cap can, however, be understood if we assume that the surface structures have changed during the past 35 years as suggested by the model of Stern et al. (1988). It will therefore be important to continue monitoring the out-of-eclipse brightness

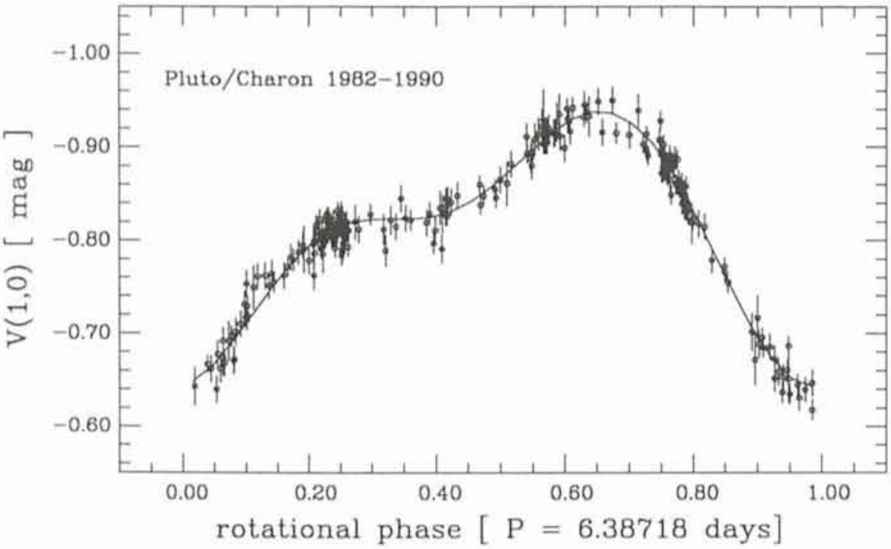

Figure 6: *The rotational light curve of Pluto and Charon observed between 1982 and 1990. The continuous line represents our analytical description of the light curve used for the deconvolution.*

of Pluto with high precision photometry to track the secular variation of the rotational light curve. The 'SHELF' model of Buie and Tholen (1989) predicts an immediate reversal of the secular variation (i.e. general brightening and a reduction in amplitude of the rotational light curve) whereas Stern et al. (1988) predict that the reversal should take place 7–17 years after passing perihelion due to the thermal inertia of Pluto's surface.

The physical parameters of the Pluto-Charon system seem to be well established now. The largest uncertainty that remains lies in the exact determination of the semi-major axis of the system which measures only 0.9″ on the sky. This is the scaling factor of the diameters and the total mass of the binary components. Future observations with high spatial resolution (e.g. with the HST or the ESO-NTT) will allow a more accurate determination of Charon's orbit. One physical parameter which is independent of this scaling length is the mean density of the system that can be calculated from the binary period and the dimensions of Pluto and Charon relative to the binary separation. The mean density of about 2 g/cm^3 indicates that the Pluto-Charon system has a high rock mass fraction similar to that of the larger satellites of the giant planets.

The mutual eclipse series of Pluto and Charon has provided us with many new aspects of the binary planet Pluto-Charon. The albedo maps computed by different observers will hopefully converge as the data of all observers will be combined. The spatial resolution that can be obtained by eclipse mapping is superior to that offered by the HST even if it would be working to design specifications. It will not be before the end of the first decades of the next century that space probes may provide more detailed pictures of the surfaces of Pluto and Charon.

Acknowledgements

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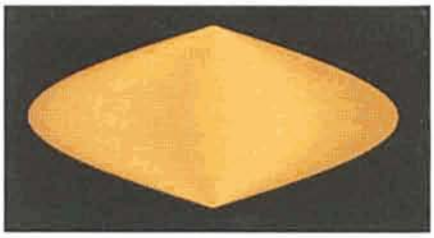

Figure 7: *Longitudinal albedo distribution on Pluto derived by deconvolving the rotational light curve in Figure 6.*

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ESO's Early History

The readers of the *Messenger* will be pleased to learn that the recent series of eleven articles about the early history of ESO, written by Professor Adriaan Blaauw, have now been collected in a book. The text has been thoroughly revised and includes photos which were not in the *Messenger* articles.

The narrative begins with the developments in the early 1950's when leading European astronomers initiated a search for the best possible observatory site under the comparatively unexplored southern sky. Ten years later, in 1962, ESO was established by an international convention and soon thereafter a remote mountain top in the Chilean Atacama desert, La Silla, was acquired. It took another decade to transform this site into the world's largest optical observatory.

ESO exemplifies the highly successful European integration in a fundamental field of science, providing European scientists with modern facilities for front-line investigations beyond the capacities of the individual member states.

Professor Adriaan Blaauw, well-known Dutch astronomer, has been closely associated with ESO during all of this time. He actively participated in many of the events described and as a former Director General of ESO (1970–74) he possesses first-hand knowledge of the organization and the way it works. A scientist of international renown, Professor Blaauw is also a noted amateur historian in his home country.

The book is available from ESO (address on the last page); the price is 25 DM, which must be prepaid by cheque or bank transfer to ESO account No. 2102002 at the Commerzbank in Munich (BLZ 70040041). Please be sure to indicate "ESO History" in your order.