B. ESO C&EE Fellows: support of individual C&EE astronomers to perform specific research programmes in astronomy or astrophysics;

C. ESO Visiting Astronomers: support of individual astronomers from ESO members states to visit C&EE institutes;

D. Participation in ESO Conferences: support of participation of C&EE astronomers in conferences organized or sponsored by ESO;

E. Exchange of Software: support of travels by C&EE astronomers to institutes/observatories in ESO member states in order to exchange software, install software systems, etc.; and

F. ESO Publications: free copies of ESO publications to C&EE institutes.

These subprogrammes are not necessarily exhaustive; they may be adjusted and others may be added, if and when other suitable modes are identified.

The first deadline for receipt of applications at the ESO Headquarters in Garching has been fixed as *15 April 1993* and the next ones will follow at three-month intervals. All applications which are received in time will be scrutinized by a special ESO C&EE Committee, composed of a small number of astronomers from in- and outside the Organization. The outcome will be announced to the applicants immediately thereafter, in most cases within one month after the deadline.

All correspondence related to this Programme shall be directed to: ESO C&EE Programme, Karl-Schwarzschild-Str. 2, D-8046 Garching bei München, Germany (Tel.: +49-89-320060; Fax: +49-89-3202362; Tlx.: 528 282 0 eo d).

It is expected that the next issue of *The Messenger* will contain an overview of the initial experience and include a list of the first support allocations.

R.M. WEST, ESO

Availability of Schmidt Plate Emulsions

On January 18, 1993, a malfunction in a compressor combined with problems in the safety system caused overheating in the cold storage plate vault outside the Schmidt building and the unexposed plates kept there were destroyed. Already exposed plates are kept in the Schmidt building itself and were not affected. Most of the plates lost were old and were used only for focus determinations and other tests. Unfortunately, our latest shipment of plates from Kodak had recently arrived and been stored, and they were lost, thus jeopardizing the scientific work at the Schmidt telescope.

To everybody's relief, Kodak was able to deliver IIIa-J, IIIa-F and IV-N plates with only four weeks' delivery time. For IIa-O, 098-04 and 103a-D emulsions, Kodak presently has problems with manufacture, and they will not be available until the end of the year. Instead of the IIa-O plates, which are the most commonly used at the Schmidt, we are looking into purchasing plates with the very similar ZU-21 emulsion from the German company ORWO. With the stock of plates that were kept in the freezers in the Schmidt building we are able to carry on with the Schmidt operations until the new plates arrive, and there will therfore be only a minor impact on the majority of programmes carried out at the Schmidt telescope.

Work is planned to begin later this year on a new plateholder that will accept emulsions on film rather than on glass. Apart from very substantial savings in operational costs, this means that programmes which are not aimed at astrometric work can benefit from new highly sensitive and fine-grained emulsions like the Kodak 4415 emulsion. Programmes that require glass plates will of course be carried out as always. After we have gained experience with this new facility, an announcement of availability will be made here in *The Messenger*.

BO REIPURTH, ESO-La Silla

Physical Study of Trojan Asteroids: a Photometric Survey

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Introduction

Since their formation in the solar nebula, asteroids belonging to the main belt have been altered mainly by mutual collisions, which take place at typical impact velocities of about 5 kilometres per second. The projectile-to-target mass ratios quite frequently reach values of the order of 10^{-3}, which can produce that catastrophic fragmentation of the target asteroid. According to many investigators, this ongoing collisional process has had a number of important consequences, ranging from the formation of dynamical families and dust bands to the insertion of meteroids and Aten-Apollo-Amor objects into planet-crossing orbits and to the generation of a variety of peculiar collisional outcomes (for example, "rubble pile", asteroids, binaries, "naked" metallic cores).

One of the main motivations for studying asteroids is that they are believed to be more "primitive" than planets, i.e. closer in size, composition, and other physical properties to the population of planetesimals from which the planets accreted. It is then natural to wonder which properties are just products of collisions and which ones in some way "remember" the primordial state, when disruptive impacts did not occur and planetesimals, in the asteroid belt as well as in other zones of the solar nebula, were gradually accumulating into planetary embryos.

Were it possible to quantitatively model the subsequent collisional evolution of

Figure 1: *The DLR CCD camera installed at the ESO 1-m telescope.*

asteroids, one could in principle reconstruct from the current asteroid properties (e.g. size distribution, relative velocities, rotations, shapes) those of planetesimals, and thus constrain the theories of planetary formation. This task is very complex and uncertain. We still know too little about the properties of asteroidal material and about the way solid bodies respond to catastrophic impacts at sizes 10^6 times larger than those observable in the laboratory. An alternative approach is that of looking in the asteroid population for subsets of objects for which we have reason to believe that the collisional process has been less intense and less effective than the average. This is just the case for Trojan, Hilda and Cybele asteroid groups (objects whose orbits have a semimajor axis larger than 3.3 AU), which hold considerable interest as they are likely to represent a set of relatively primitive bodies which may have experienced little thermal and collisional evolution since the time of their formation.

The dynamical scenario of the outer belt is strongly influenced by the gravitational interaction with Jupiter. With a few exceptions, the outer belt asteroids (OBA) have orbits which are either in resonance with the giant planet or are confined between two different resonances. The Cybeles are located between the 2:1 and 5:3 resonances with Jupiter (mean semi-major axis a = 3.4 AU), the Hildas are found at the 3:2 resonance (a = 4.0 AU) and the Trojans are trapped in the L4 and L5 Lagrangian points of Jupiter's orbit at a = 5.2 AU. 279 Thule is the sole object known to occupy the 4:3 resonance. There, both the number density of asteroids and their relative velocities are significantly lower than in the main belt. Therefore, these bodies should show a lesser degree of collisional alteration, and could allow us to look farther and more clearly into the primordial properties of planetesimals. At the same time, any differences in physical properties with respect to the main belt might provide evidence on the way collisions are currently causing the asteroids to evolve away from their primordial state.

Most of the OBA bear evidences of redder and darker surfaces when compared with the main belt asteroids and their spectra show a reddening in the spectral slope with increasing heliocentric distance, which implies a change in composition. The major taxonomic types among the distant asteroids are quite rare in the main belt and are currently unrepresented in terrestrial meteorite collections. The investigations of the physical properties of the OBA, and the subsequent understanding of their nature and origin, will have a direct implication for any theoretical study on the evolution of the solar system.

Rotational Properties of Outer Belt Asteroids

Some important physical properties of the asteroids can be inferred from lightcurve observations. These include the rotational period and, through some modelling effort and/or by using simplifying assumptions, the overall shape of the body and the direction of its polar axis. Statistical analyses of these rotational properties have been carried out and have revealed a complex scenario, where collisions do indeed appear to have played a dominant role (see Binzel et al. 1989).

The lack of photometric information about OBA is due to their great heliocentric distance and their corresponding faintness, nevertheless the advances in astronomical detector technology have brought the most of the OBA at reach of the small- and medium-sized telescopes, allowing American and European groups to carry out observations to study these faint objects (French, 1987; Hartmann et al., 1988; Zappalá et al., 1989; Binzel and Sauter, 1992). The first results of these studies

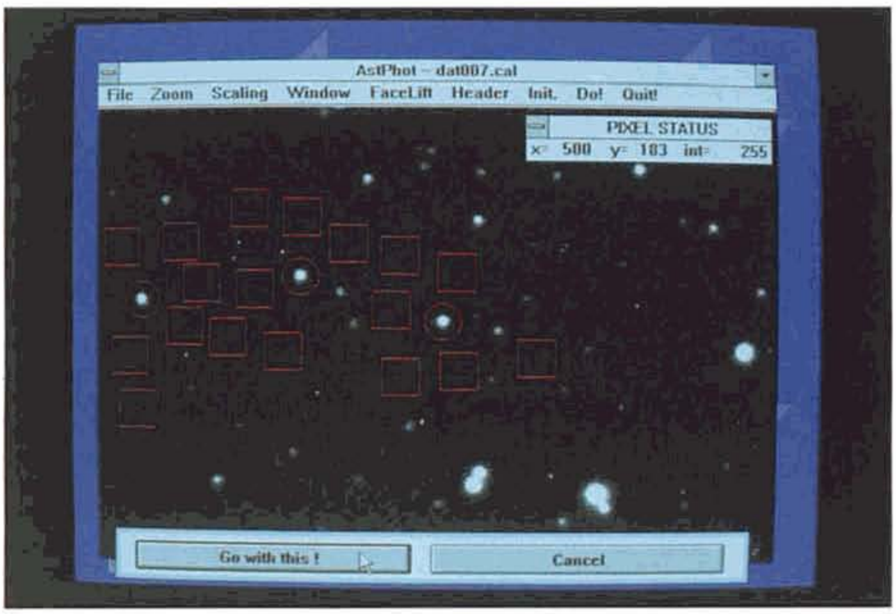

Figure 2: *This picture shows a session of the photometric reduction package in use at DLR. The circles define the integration area for the asteroid and the comparison stars. The sky background is sampled in the areas delimited by the square boxes.*

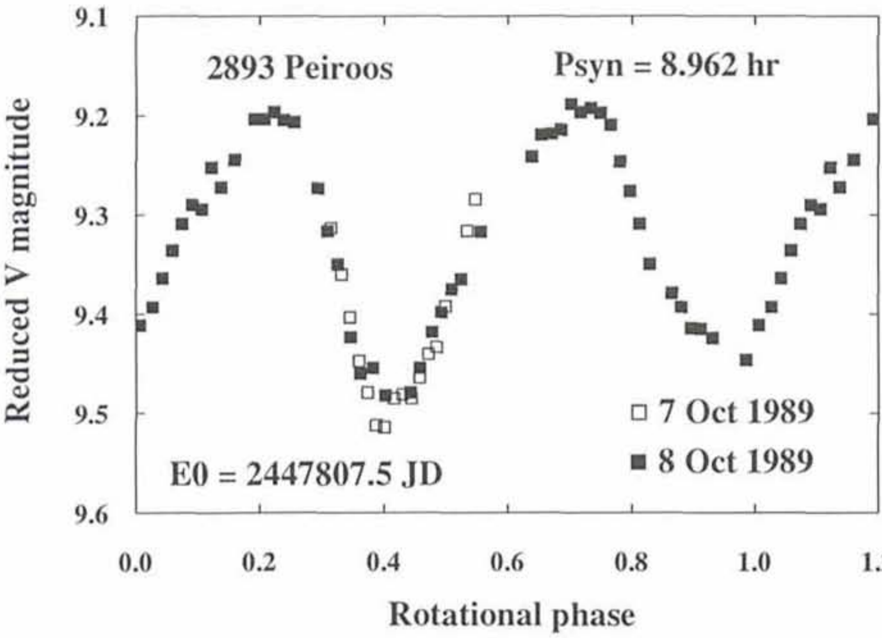

Figure 3: *Photometric measurements, extracted from repetitive imaging as shown in Figure 2, are used to determine the rotational lightcurve of the asteroid. From measurements of October 1989, we obtained this composite V-lightcurve for 2893 Peiroos. The data points beyond the rotational phase 1.0 are repeated.*

have outlined an interesting trend: the Trojan asteroids, and possibly the asteroids belonging to the Hilda group, would display larger average lightcurve amplitudes compared to those of the main belt asteroids (MBA), implying a more elongated shape. At this stage, however, it is not clear whether the high lightcurve amplitude is a common feature among the Trojans, or whether it is due to the presence in the amplitude distribution of a tail of very few, very high amplitude asteroids (Hartmann and Tholen, 1990).

Should the collisional evolution of the MBA be significantly different from that of the OBA, we would also expect to observe differences in their rotational rate distribution. In the main belt for example, Binzel et al. (1989) found that the rotational period distribution of the asteroids in the size range 50~125 km can be fitted with a linear combination of two different Maxwellians, this fact being interpreted as the evidence of the coexistence of two families of rotators at a different stage of collisional evolution. At present, however, it is impossible to perform such an analysis on the rotational rates of the Trojans with sufficient level of reliability, owing to the poor data set available.

The Survey

To contribute to establish a statistically representative sample of the rotational properties of the OBA, we started in 1988 a systematic survey to collect photometric lightcurves of the asteroids belonging to the Trojan, Hilda and Cybele groups, which is still on-going (Mottola et al., 1990; Gonano et al., 1991; Di Martino et al., 1992).

Most of our observations were carried out at the ESO 1-m telescope using the DLR CCD Camera, an easily transportable system, that we have optimized both in the hardware and in the software for the application in this field of research. In Figure 1 the DLR CCD Camera installed at the ESO 1-m telescope is shown. The DLR CCD Camera was manufactured by Photometrics Ltd. (USA), it utilizes a Thomson TH-7882 charge-coupled device and is controlled by a 486 PC.

A CCD sensor presents several advantages in dealing with some of the peculiar experimental difficulties in asteroid observations. The determination of the rotational properties implies to observe the asteroid continuously and for long runs. For this reason it is often necessary to observe at high values of airmass or during dawn or dusk. The imaging capabilities of the detector allow to perform differential photometry with comparison stars present in the field, making it possible to have an accurate extinction correction and sky background subtraction even under these critical conditions. The two-dimensional information provided by the array is also essential to overcome the problems of performing an accurate photometry when the asteroid crosses crowded stellar fields and relaxes the constraints on tracking. Furthermore the high quantum efficiency, the linearity of the solid state detector and its low read-out noise are necessary conditions to obtain the required photometric accuracy to detect features in the lightcurves, which have sometimes an amplitude of only a few hundredths of a magnitude.

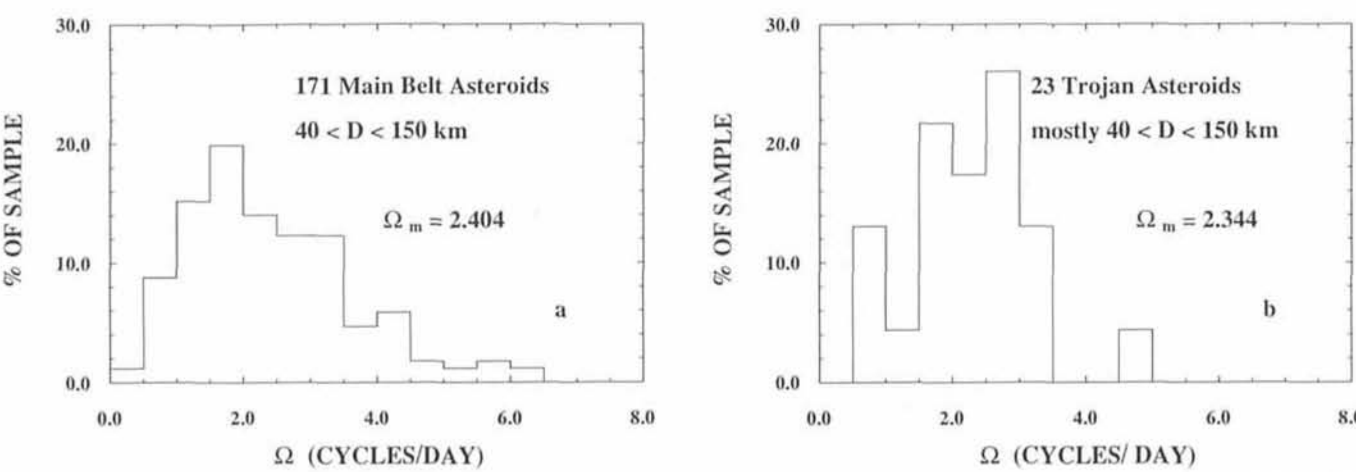

Figure 4: *(a) Histogram of the rotation rates for a sample of main belt asteroids, where the range of 0 to 8 revolutions/day has been divided into 16 equal bins. (b) The same as (a) but for the Trojan asteroids with known rotational period.*

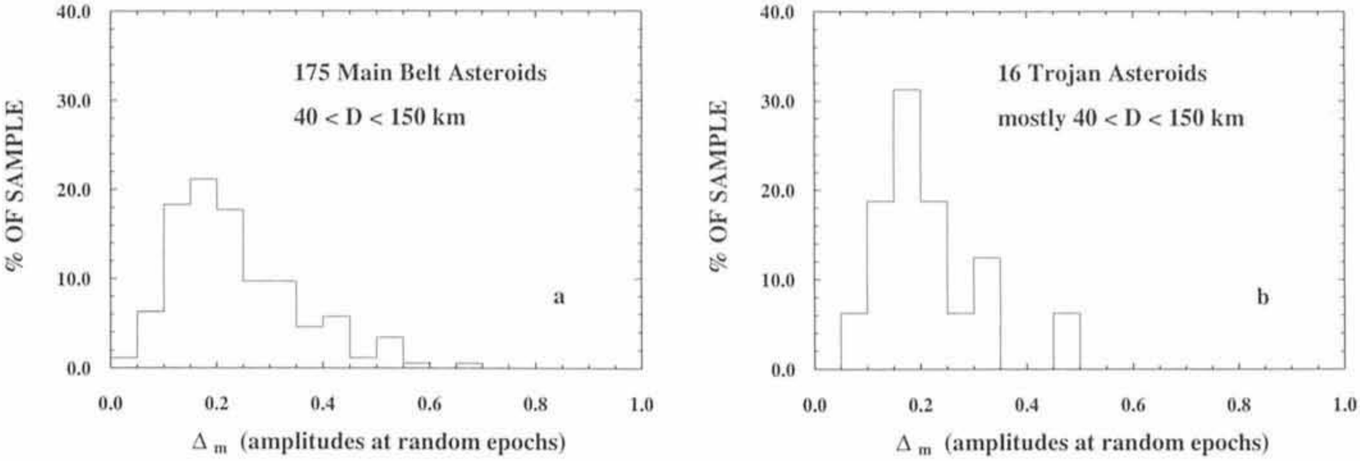

Figure 5: *(a) Histogram of the lightcurve amplitudes for a sample of main belt asteroids. (b) The same as (a) for the Trojan asteroids observed during the survey.*

Since the good time-sampling is essential to compute reliable amplitudes and rotational periods from the lightcurves, the manual intervention (and hence the occurrence of mistakes) during the operation of the camera at the telescope has been reduced. The entire acquisition sequence is preprogrammed and played back by the camera computer. This automatic sequence includes the filter positioning, the exposure timing, the display and storage of the scientific frames, and the flagging of the saturated pixels. Some of the operations are performed concurrently (e.g. image exposure and storage of the previous frame). The dead times between two exposures are then significantly reduced, limited in some cases only by the readout time of the CCD.

The data reduction is performed in the camera computer using the software package for CCD image processing developed at DLR. This allows us to perform the complete reduction of the data during daytime after each observing night, to optimize the sharing of the telescope time between the different targets, preserving the good sampling and the completeness of the lightcurve coverage. The instrumental fluxes of the asteroid and of the comparison stars present in the frame are evaluated applying a synthetic aperture photometry procedure (see Fig. 2). The "light growth curve" method (Howell, 1989) is used to determine the best aperture size and the background level.

Composites are derived combining the single lightcurves by using a Fourier fitting procedure (Harris et al., 1989). The order of the Fourier polynomials is chosen according to the temporal sampling of the lightcurves. The best-fit polynomial is then evaluated for the different trial periods and the solution is determined by comparing the residuals of the different fits. As an example of the final output, in Figure 3 we show the composite obtained from our lightcurves for the Trojan asteroid 2893 Peiroos.

Preliminary Results of the Survey

We have compared the distributions of the rotational periods and the lightcurve amplitudes of Trojan asteroids with the distributions of a selected sample of main belt asteroids. As a reference group we chose a sample of main belt asteroids in the diameter range 40–150 km from the Asteroid Photometric Catalogue (Lagerkvist et al., 1989). Particular care has been devoted to the selection of the reference sample, in order to limit the incidence of the observational bias present in the catalogue (see discussion in Binzel et al. 1989).

The sample of Trojan asteroids we used for the analysis of the rotational period distribution is based on the present results of our observational survey and also includes several objects observed by French (1987), Hartmann et al. (1988), Zappalà et al. (1989), Hartmann and Tholen (1990), Binzel and Sauter (1992) and by others. Figures 4 a and b show the histogram of the rotational frequencies of a reference group of 171 main belt asteroids and that of 23 Trojans, respectively. By applying the Kolmogorov-Smirnov test, we have checked the null hypothesis that the two observed distributions derive from the same population. The result of the test is that the two distributions cannot be distinguished at the 90 % confidence level.

We have similarly compared the distribution of the lightcurve amplitudes of 16 Trojans observed during this survey and of a reference group of 175 main belt asteroids (see Fig. 5 a, b). To account for the fact that the main belt asteroids are normally observed at larger solar phase angles than the distant Trojans, we have reduced the observed amplitudes of the MBA group to zero phase angle by using the Amplitude-Phase relationship (APR) described by Zappalà et al. (1990). Also in this case the Kolmogorov-Smirnov test gives $Q \ll 90$ %, indicating that no systematic difference between the two distributions is detected with this data sample. It is interesting to note that the distribution of the amplitudes we measured for the Trojans in this survey has a mean value (A = 0.21 mag), which is very close to that of the main belt asteroids (A = 0.22 mag) in this diameter range. In this sense our sample taken by itself does not provide the evidence for the presence of anomalously elongated shapes among the Trojans. These results on the comparison between the rotational period and lightcurve amplitude distributions of main belt and Trojan asteroids are not conclusive yet. More observations to increase the sample sizes are needed to improve the power of the statistical results. The completion of this survey will provide the required observational data set to take the first steps on the origin and the evolution of the distant asteroids.

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Dust in the Earth's Atmosphere Before and After the Passage of Halley's Comet (1984–1987)

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Everybody knows that with the exception of those who study the Sun, members of the astronomical profession must work at night to be able to record the faint light from the objects of their interest. It is true that CCD flat fields are often made at twilight, but otherwise it is necessary to wait until the Sun is far below the horizon and there is no more straylight in the atmosphere, before the "real" astronomical observations can start.

It is therefore always a surprise, especially to visiting colleagues, to meet astronomers/physicists, who are busy observing during twilight and dawn, when the sky is still very bright. And it seems even more strange that when it finally gets dark, then these observers close their telescopes and return to their offices and homes!

At the Abastumani Astrophysical Observatory in the Republic of Georgia, located near the border with Turkey in the southern part of the Caucasus mountains, you will meet observers of all three types. While some of them study the Sun with imaging and spectroscopic telescopes, others like ourselves observe the emissions from the Earth's atmosphere in the daytime, during twilight and dawn, and also during the night, when still other colleagues are busy unlocking the secrets of distant stars and galaxies.

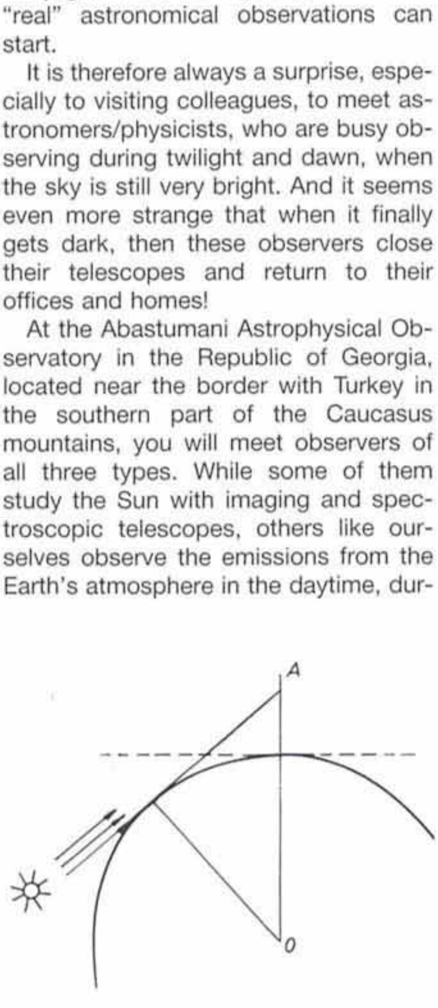

Figure 1: *The twilight phenomenon. An observer on the Earth's surface who looks up towards the zenith, only receives scattered light from those layers which are illuminated by the Sun's rays.*

We know that most astronomers have little experience with our kind of research and would therefore like to illustrate it by some examples. It is of course normally considered to be more of "geophysical" than of "astronomical" nature, but, as we shall see below, it may however also have some implications which are of interest to solar system astronomers.

The Twilight Sounding Method

Among the many interesting questions which concern the meteor showers associated with comet P/Halley, i.e. the *Orionids* with a maximum around October 21 and the *Eta Aquarids* (around May 4), is whether or not a particular activity was connected with the latest approach of this famous comet to the terrestrial orbit in 1985–1987.

Meteoric aerosol which enters into the Earth's atmosphere can be detected by the method of *twilight sounding*; this has been done many times in the past, see e.g. Fehrenbach et al. (1972); Divari and Mateshvili (1973), Mateshvili (1974), Link (1975) and Mateshvili and Mateshvili (1989).

The twilight phenomenon is explained by the fact that when the Sun sets below the horizon, its rays continue to illuminate the higher layers of the atmosphere. To begin with, these rays reach all layers, but as the Sun sinks, progressively higher layers come into the Earth's shadow and cease to be in the sunlight. The scattered light from the sky comes increasingly from the highest layers, but since the scattering efficiency falls off with the altitude (i.e. with the density) rather rapidly, we receive at any time mostly the scattered light from a rather narrow, sunlit atmospheric layer. A simplified scheme of the twilight phenomenon is shown in Figure 1.

The intensity of scattered light from point A is given by the relation:

$$I(\lambda) = I_0(\lambda)\,\omega_0\,P^m(\lambda)\,m\,\tau(\bar{H})$$

where $I_o(\lambda)$ is the extra-atmospheric solar brightness, ω_o is the size of the solar disk, m is the air mass, P is the vertical transmittance of the atmosphere, $\bar{H}(\lambda)$ is the instantaneous altitude of the Earth's shadow, τ is the optical thickness which is given by the expression:

$$r(\bar{H}) = \int_{\bar{H}}^{\infty} \sigma(\bar{H})\, d\bar{H}$$

where $\sigma(\bar{H})$ is the volumetric scattering coefficient (Rosenberg 1963). So, $I(\lambda)$ is therefore proportional to scattering coefficient $\sigma(\bar{H})$ and N_{aer}, the aerosol or particle content per unit of volume.

In Abastumani, we use for our twilight observations a photoelectric photometer with an interference filter that is centred at λ 610 nm. During the evening twilight phase we then register the decreasing total intensity from a sky area

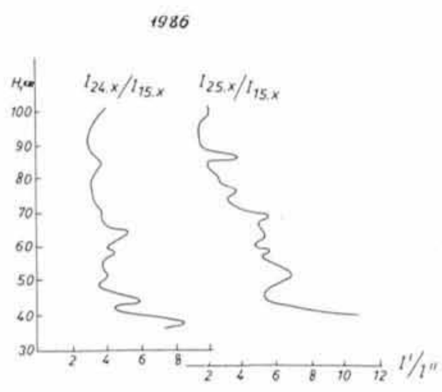

Figure 2: *Intensity ratios as a function of altitude, as observed on October 24 and 25, 1986, relative to October 15, 1986, i.e. before the Orionid period. The ratios are much larger than unity, and the scattering is therefore much larger at and after the maximum of the stream, than before. This shows the injection into the atmosphere of dust particles.*