

# THE MEASUREMENT OF THE SKY BRIGHTNESS AT MERATE OBSERVATORY

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**ABSTRACT.** We describe the problems met using the telescopes of Merate Observatory, the branch of Brera Astronomical Observatory. From the point of view of the data analysis, we discuss how to introduce a satisfactory correction of the variable extinction coefficient, giving also some examples. We also measured the sky brightness, obtaining  $V=18.2$  mag/arcsec<sup>2</sup>. The light pollution is responsible for such a bright background and we present pictures showing its effects. We are limiting it trying to persuade public administrations to reduce the light scattered toward the sky by using cutoff lamps and putting out commercial searchlights. The need of a law which safeguards astronomical activities is stressed.

## 1. The telescopes of Merate Observatory

Since a long time, the utility of small telescopes located near to research Institutes is re-evaluated, as they can provide useful surveys of variable stars and peculiar objects, especially over a long-time baseline. This kind of survey cannot be further done at large observatories, owing to competition in dividing time at big telescopes and the closing of the small ones for budget problems.

For this reason, a constant effort was made to keep the Merate telescopes at a reasonable level of performances, in order to carry out such long-terms programs, often requiring high-precision measurements too (photometry with a precision better than 0.010 mag, for example). The 50-cm Marcon telescope is equipped with a photon-counting, single channel photometer;  $UBV$  and  $uvby\beta$  filters are available. Usually, stars brighter than 9.5 mag are measured with the requested accuracy. For fainter objects, we have equipped the 102-cm Zeiss telescope with a CCD camera, allowing us to observe successfully fainter objects. Moreover, we are now substituting the optics of the Ruths telescope, replacing the old 137-cm metallic mirror with a 134-cm Astrosital one; to do that, the generous contribution of CARIPLLO Foundation was of paramount importance. The substitution will be completed in late 1998; it is foreseen to automatize the movements of the telescope.

The three domes are also open to public to sightsee celestial objects in some nights each month, usually around the Moon first quarter.

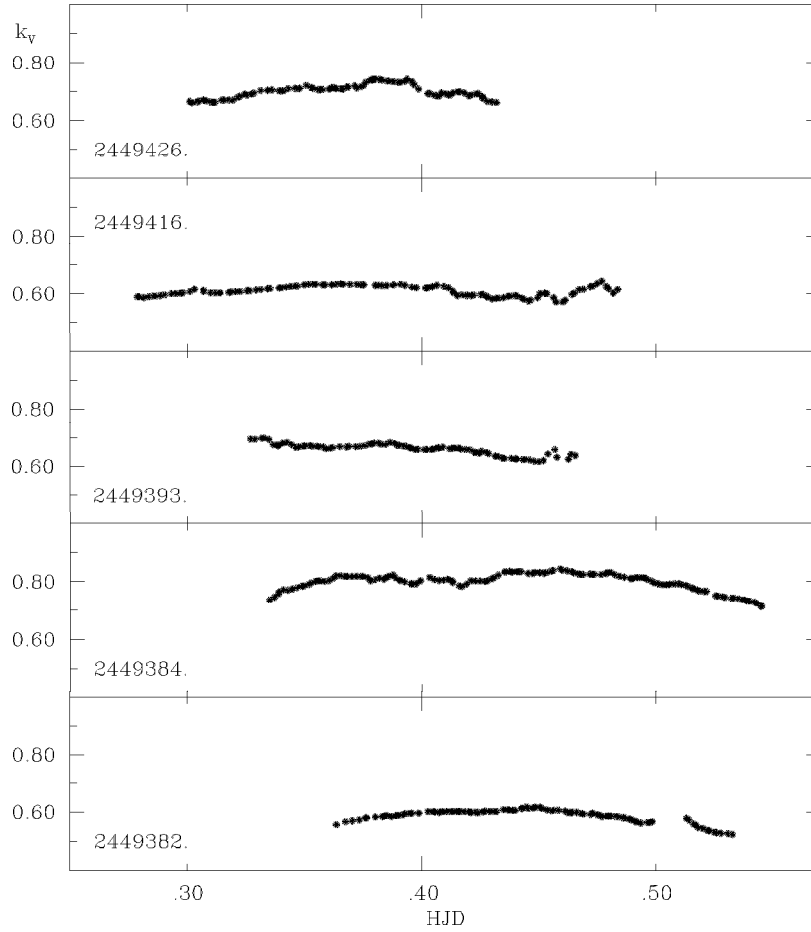


Fig. 1. Behaviour of the extinction coefficient in  $V$  light as observed at Merate Observatory on some nights in early 1994.

## 2. The measure of the extinction coefficient

When the measurements of the star brightness must be very accurate, it is necessary to determinate the extinction coefficient  $k_\lambda$  in a very reliable way.

In such a case, the usual Bouguer's line cannot be recommended since the constancy of  $k_\lambda$  (for the whole night in all the directions) is a constraint very hard to satisfy. As we measured a lot of times, slow variability of  $k_\lambda$  is a common phenomenon in a night, also in sites considered as photometric ones, as the high altitude ones (drifts of a few hundredths of mag/airmass are observed, see Poretti & Zerbi 1993a, 1993b). At lower altitude sites (Merate id 328 m above the sea level) an erratic and large amplitude (more than 0.10 mag/airmass) variability is more frequent. In general, it mimics the

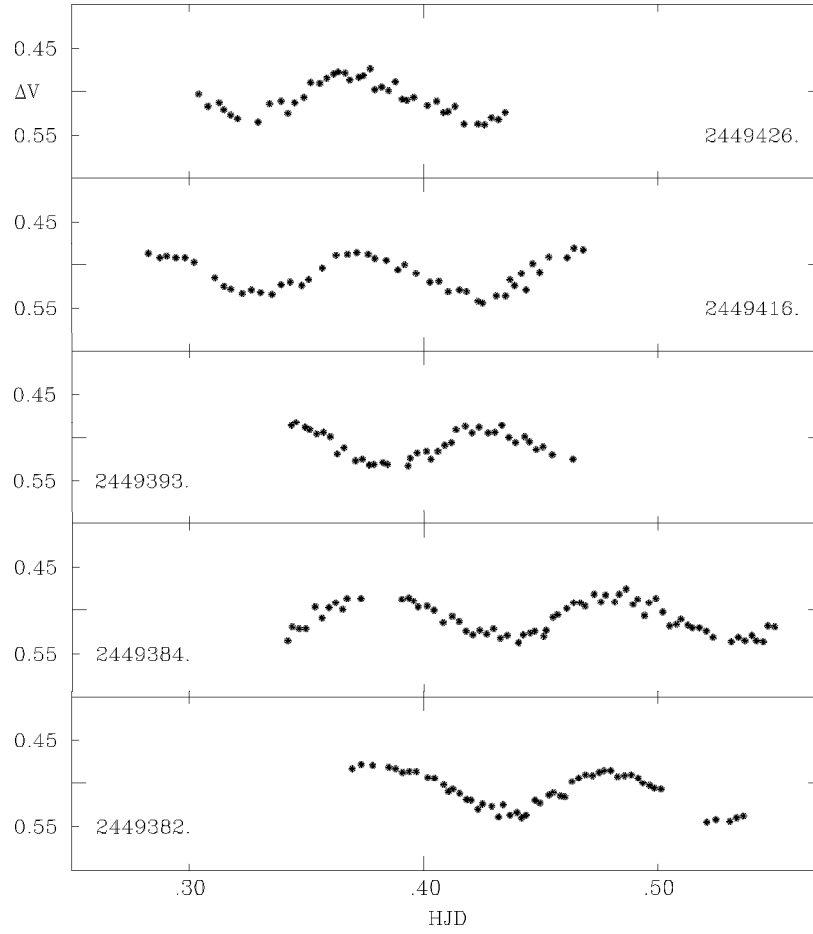


Fig. 2. Light curve of the  $\delta$  Sct star AZ CMi as observed in the same nights of Fig.1: the variability of the extinction coefficient was corrected by our method and satisfactory light curves were obtained.

variations in the lower part of the atmosphere, which is influenced by the local conditions on the ground: presence of woods, lakes, industrial and urbanized areas ... Moreover, also temperature and relative humidity changes can modify the  $k_\lambda$  value, especially in the first hours of the night. The passage of medium altitude clouds is also responsible for long term waves in the measured flux.

In such conditions, the differential photometry is strongly recommended to minimize these effects. However, it cannot ensure the requested accuracy when the fluctuations of  $k_\lambda$  are large even if the comparison stars are not very far. For this reason, we developed a method allowing us to monitor continuously the transparency variations. To do that, the instrumentation is kept under a tight control (cooled, always on, no hardware changes.);

an artificial source is inserted in the filter wheel to check at the beginning of each night if the instrumental response is the same. We always verified that within the statistical errors, confirming that a photon counting photometer can provide a high-level stability.

Our main research field is the study of short period variable stars (see Poretti & Mantegazza 1992 and references therein); the target stars and its two comparison stars are measured for all the night. In such a way, it is quite easy to build the graphs described by Poretti & Zerbi (1993a, 1993b) to calculate  $m_0$ , the *instrumental magnitude above the atmosphere* of a comparison star. Once  $m_0$  is known,  $k_\lambda$  can be evaluated every time this star was measured, resolving the Bouguer formula

$$k_\lambda(t) = (m(t) - m_0)/X \quad (1)$$

where  $X$  is the airmass,  $m(t)$  and  $m_0$  are the magnitudes of the reference star inside and outside the atmosphere, respectively. Figure 1 shows some examples of the variability of the  $k_V$  coefficient as observed when measuring the  $\delta$  Sct star AZ CMi at Merate Observatory (Poretti et al. 1996). As can be easily noticed, it is hard to see a constant behaviour. In the JD 2449393 night the continuous drift was of about 0.10 mag/airmass, while in the JD 2449384 night the parabola-like arc spans 0.15 mag/airmass. Note that fluctuations starting after the half of the JD 2449416 night, in a quite unpredictable way. Note also the presence of waves in the  $k_V$  curves, practically in all the nights, and the changing mean level of the  $k_V$  value, suggesting that an average value should not exist.

The method described in the quoted papers and briefly recalled here provides a satisfactory correction of the extinction since the instantaneous value can be used all the times the magnitude difference stars are calculated. Figure 2 shows the very small amplitude light curve of AZ CMi as obtained from the measurements carried out in the same nights: as can be seen, the regular cycle of variability is well described by the single points (see Poretti et al. 1996 for further details on the frequency analysis). It is important to note that its application does not require any additional measurement, i.e. no time is subtracted to the main programme.

### 3. The sky brightness: the procedure to measure it

To measure the sky brightness, we used the 50-cm telescope and the photon-counting instrumentation. We give here a short description of the procedure, emphasizing some methodological aspects.

To establish the relationship between counts per second and magnitude, a standard star was measured and the sky as observed near it was subtracted. Therefore, the absorption correction was applied to transform the catalogue magnitude to the measured one. If the star is very bright, the dead-time correction was also applied; Poretti (1992) describes a reliable method to determine it. Once we did that, the sky was measured in different positions. To calculate the brightness per arcsec<sup>2</sup>, we need for the diaphragm area. The exact sizes of the diaphragms can be determined by the crossing time of a bright star (an eyepiece allows us to see the diaphragm wheel); this procedure is suitable for larger ones, but not recommended for smaller ones. The latter values can be better established by performing some sky measurements in the same position, allowing us to

obtain very accurate area ratios; once the larger areas were determined by means of the crossing times, the smaller ones can be derived. In all these measures, do not forget to subtract the value of the dark current.

#### 4. The sky brightness: the Merate values

To check the dependence of the measured value from the position, we performed a series of measurements in different parts of the sky (September 1990). Of course, the darkest point was the zenith, where we measured  $V=18.2$  mag/arcsec<sup>2</sup> in average local conditions ( $k_V=0.50$  mag/airmass, no moon, no wind); this value was taken as a reference. Then we moved the telescope mapping the sky toward the south. Table 1 lists the observed increases in brightness: note that 40–45° above the horizon the sky is already 1.0 mag brighter than at zenith. To yield a better evidence of this fact, Fig. 3 shows a fish-eye picture of the sky as seen from Merate observatory; the camera was pointed toward North. The pollution by the light of the neighbour towns (Merate, Milano, Lecco, Como, ...) is impressive.

**Tab. 1 - Increase of the sky brightness at different declinations and hour angles. (0 h, +45°) corresponds to the zenith value, i.e.  $V=18.2$  mag/arcsec<sup>2</sup>.**

Decl.	Hour angle		
	- 2 h	0 h	+2 h
+ 45°	0.08	0.00	0.09
+ 35°	0.19	0.08	0.18
+ 25°	0.30	0.19	0.35
+ 15°	0.60	0.40	0.62
+ 05°	1.02	0.61	0.95
- 05°	1.32	0.90	1.28

#### 5. Preserving the observational capabilities

We met a lot of problems in defending the capabilities of our observatory. Since it is located in a crowded area, there are often conflicting interests from different people. However, we did an effort to create a favourable climate of opinion about our activity, especially by means of straight contacts with local administrators. Since the results of the measurements carried out in our Observatory are regularly published in professional journals, this is a relatively easy task.

To avoid light dispersion toward the sky, we mainly try to convince them to use cutoff lights. On the basis of a collaboration plan, they ask for our approval about the lightings of large plants, even if the fulfilment of our suggestions cannot be considered as mandatory. In general, we met an attentive audience of our opinions. However, we stress the importance of a regional or national law which establishes the safeguard of astronomical sites, both from a scientific and a cultural point of view. In the lack of that, disputes can easily arise. As an example, we had a legal controversial against a

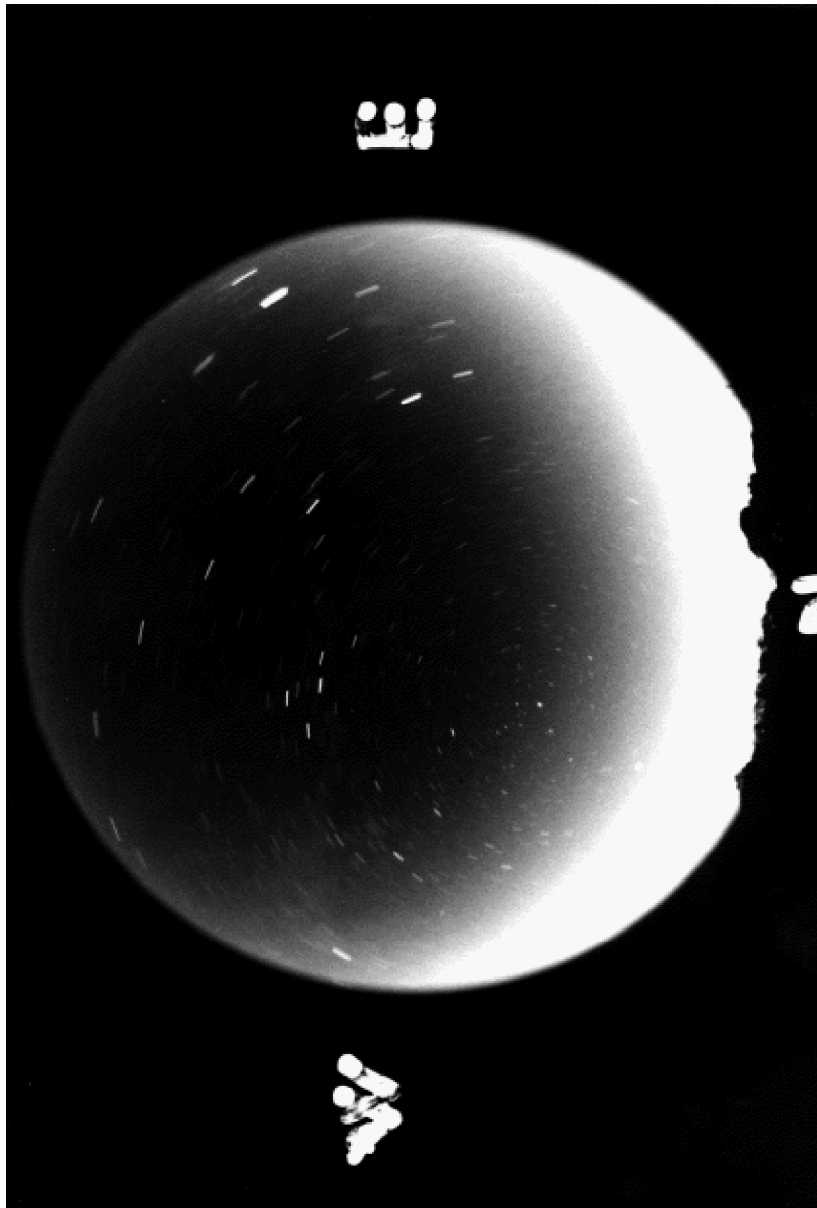


Fig. 3. Picture of the night sky taken with a fish-eye objective from Merate Observatory. Exposure time was 15 minutes, November 1990. The camera was pointed toward North.



Fig. 4. The effect of a searchlight on the sky seen from Merate Observatory. Its damage to the observational activities was demonstrated and its putting out was decided by the public authority

discotheque which placed a powerful searchlight on the roof to be seen at large distances (Fig. 4). On the basis of a collection of evidence, official institutions ordered to switch off the searchlight since its damage to the observations carried out in our institute was evident.

### **Acknowledgements**

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