PART 7: MEASURING POSITIONS ON PHOTOGRAPHS

1. Measuring prints of meteor photographs

A beautiful meteor photograph may have some aesthetic value to a meteor photographer, but if the result is to also have a scientific value it is of great importance that all the data is carefully recorded. The photographer may help to speed up the reduction work for the *IMO* by identifying some background stars on the print and by preparing some of the measurements.

1.1. Identification of a print

Identify a print as complete as possible, to avoid any doubts in the case of double station photography. Most of the information can be written on the back of the print.

Date:	19 .... /..... /..... (yy/mm/dd)
Observer:	....
Observing site:	....
	$\lambda = \quad ^\circ \quad ' \quad ''$ E/W; $\varphi = \quad ^\circ \quad ' \quad ''$ N/S;
	height = m above sea level
Exposure time:	Begin $^{h} \quad ^{m} \quad ^{s}$ UT; End $^{h} \quad ^{m} \quad ^{s}$ UT
Meteor time of appearance:	$^{h} \quad ^{m} \quad ^{s}$ UT
Visual magnitude:	.... ^{m}
Shutter	.... breaks per second; type of shutter ....
Number of interruptions	.... , meteor duration .... s
Film number	....
Negative number:	....
Remarks:	

1.2. Format of the prints

For further processing of the data we need two prints:

– A print which covers the entire negative

– An enlargement of the region around the meteor.

For instance:

– The entire photo printed to 12 cm×9 cm.

– Detail of 12 cm×9 cm, with an enlargement factor of about 3 or 4.

The print of the entire photo must allow the determination of the plate center (the centre of the frame rectangle). When the camera has been directed to a pre-defined point in the sky, for a double station project, this point should coincide with the plate center. Aiming a camera accurately without using an azimuth or equatorial mounting is thus rather difficult.
A print with details near the meteor allows the determination of specific stars in that area.
For the measurements bear in mind that the image of an all sky mirror camera is a reflected image and thus the orientaion is different from a "common" image of the sky. For the measurements this is no general problem, but it must be borne in mind. For calculations you have to remember to reverse one axis (see below).

2. Measuring original films or plates

Of course, each copying process reduces the accuracy of an image. On the other hand, copying allows us to enlarge the scale and makes measurements possible without expensive measuring devices.
These devices are needed to measure distances on the original images. The required accuracy is of the order of some 10^{-3} mm. Coordinate measuring machines are specially designed for this purpose. If you have access to such a device, it is to be preferred over measurements on prints.
When placing original plates or films in such a machine, be careful to avoid damages to the emulsion. Regarding the measurement itself, follow the instructions given for the particular device used.

3. Comparison stars

In order to compute the correct position of a meteor, a number of comparison or reference stars need to be known.
The minimum number of stars is three: in such a case it is not possible to get any idea about the errors on the measurements themselves. Therefore, in practice, normally 5 or 6 reference stars are chosen. These reference stars have to be *distributed evenly around the meteor*. They should not be on or near one line, as this gives rise to large uncertainties. An example of a good and a bad choice is given in Fig. 7-1.

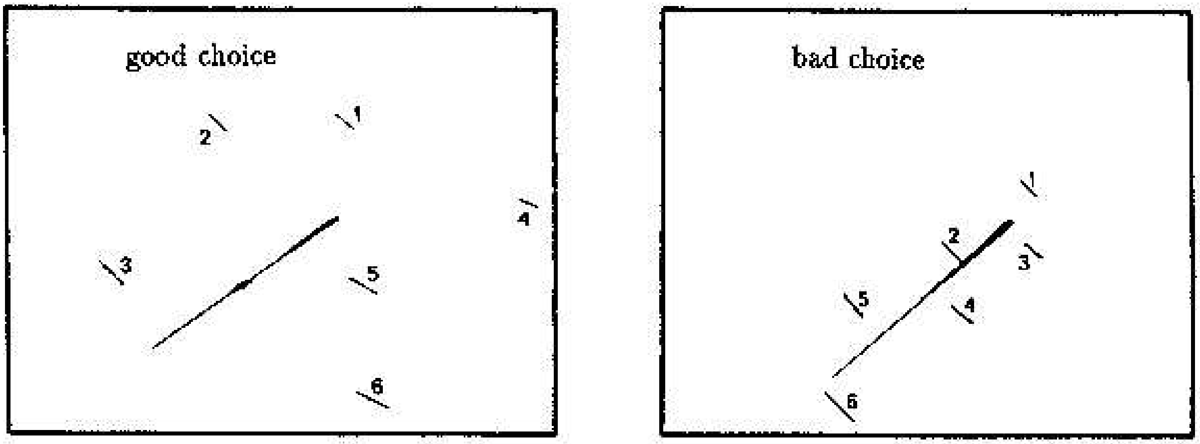

Figure 7-1: Examples for a good and bad choice of comparison stars for position measurements.

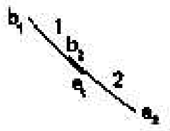

Figure 7-2: Trails of stars having nearly identical declinations may overlap and are therefore not suited as reference stars for position measurements.

A reference star *must not be a component of a double or multiple star.* The term "multiple star" must be considered in the widest context, including stars that are between 0.3′ to 3′ apart in the sky including official multiples as well as "true" multiple star systems. It is often not possible to separate the components on the photo, and this may result in errors of the order of the distance between the components.

A star that overlaps another star trail on a non-guided exposure may not be used (stars of about the same declination). This is especially necessary for long exposure times (in excess of 15 minutes).

In the neighbourhood of the pole there are no problems. The star trails here are very short. As a result even more fainter stars can appear on the photo. Any inaccuracy in the measurement will, however, result in a large error in Right Ascension, though the absolute angular error remains unchanged.

Of course, the equatorial coordinates of the reference stars, α and δ need to be known. Therefore we need both a star atlas and a star catalog. For this, the "Atlas of the Heavens" of Bečvar or "Norton's Star Atlas" or "Sky Atlas 2000.0" may do. The first of these depicts the sky down to limiting magnitude 7.5, the second one to 6.5. One of these atlases should be used in combination with the "Atlas of the Heavens - Catalogue 1950.0" (to visual magnitude 6.25) or "Sky Catalog 2000.0". The numbers in this catalogue are those of the Boss General Catalogue (GC). Mentioning the GC-number is sufficient as identification. Another numbering system often used is the Flamsteed identification, for instance. GC 4973 = 50 Per, 5.59^{m}.

There are other more elaborated atlases and catalogs, but the above mentioned ones are more generally known and widespread among amateurs.

4. The measuring work itself

Once the reference stars have been chosen, we then have to measure their rectangular coordinates (and also the position of the meteor) relative to some randomly chosen rectangular x and y axes.

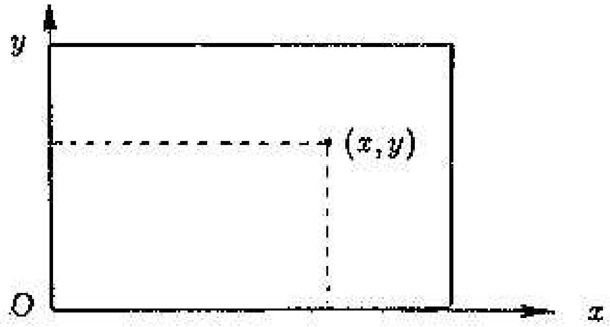

Figure 7-3: Axes on the print. The bold frame marks the entire print. The point 0, or $(0, 0)$ with its coordinates, is the origin of the coordinate system.

Mostly, the axes are chosen along the edges of the print, with the zero point in the bottom left hand corner. The x and y values are then measured to 0.1 mm accuracy. For instance: $x = 80.6$ mm ,$y = 45.2$ mm. For measuring a clear plastic ruler with divisions every 1 mm is very suitable though the tenths of a mm have to be estimated. For measuring the x-coordinates, the zero point of the ruler is positioned on the left edge of the print (y-axis). and the ruler itself is kept as parallel as possible to the bottom edge of the print (x-axis). This can easily be achieved by fixing the print truly square to a drawing board.
Similarly for the y coordinates the zero point of the ruler is positioned on the bottom edge (x-axis) and the ruler kept parallel to the left edge (y-axis).
The fact that the measuring staff may not be kept perfectly parallel to the edge of the print produces only a minor error. When the edges of the print are not straight (badly cut), or they are not perpendicular, then the print should be glued on a sheet of paper, to give another rectangular x, y coordinate system.
The rest of the procedures are described in detail in *IMO's* "Photographic Astrometry" brochure (Steyaert, 1990). A blank *IMO* astrometry form is given on the next page.

References and bibliography:

Steyaert C., 1990: Photographic Astrometry. (*IMO* Monograph N° 1). The International Meteor Organization.

IMO – The International Meteor Organization

The Photographic Meteor DataBase – PMDB

ASTROMETRIC FORM
Vol.: rec.: .

Date (dd/mm/yy) ____/____/____ **Time of meteor** (hh/mm/ss) ____/____/____UTC
Visual reference ________ Magnitude ______ Meteor shower __________

Site of observation Latitude $\varphi =$ ____° ___′ ___″ **Observer** __________
Longitude $\lambda =$ ____° ___′ ___″ __________
Elevation $h =$ _____ m __________
Location ____________________ __________

Camera lens $f =$ _____ mm focal ratio $d/f = 1:$ __________
Exposure start (UTC) ____^{h} ___^{m} ___^{s} film identification __________
end (UTC) ____^{h} ___^{m} ___^{s} negative number __________
Emulsion __________ ISO ___ after developing
Developed in ________ for ______ minutes at ________°C
Shutter type: DC / AC / Synchr / LCD __________ breaks/second
blade angles ____° __________breaks measurable along the trail

Reference stars Catalog: GC / HD / SAO / ...

Designation	Number	x begin	y begin	x end	y end

Estimated plate center $\alpha =$ ________°, $\delta =$ ________°

Points on meteor trail

Identification	x	y	Identification	x	y

Remarks