Astronomical Society of
Southern Africa
SYMPOSIUM 2002

Recent ASSA Results on Comets and Meteors

T P Cooper
Director Comet and Meteor Section, Astronomical Society of Southern Africa
P O Box 14740 Bredell 1623, South Africa
Email tpcoope@mweb.co.za

Abstract
Since I took over as Director of the Comet and Meteor Section 10 years ago, members have produced some useful scientific contributions on several comets and meteor showers. In this paper I will summarise the observing methodology, show a selection of results and review areas where further contributions can be made.

1. Methodology of Comet Observation

Observations of comets can be made visually, by CCD or photographic imaging, and by sketching. All methods have been used by ASSA members in recent years on several, mainly brighter comets. Visual observations are used to measure the brightness and morphology of comets. Images and sketches are useful as permanent records of details within comets, and can also be used for direct measurements of cometary dimensions. CCD imaging can also be used for brightness measurements, especially useful for fainter comets.

2. Visual Observing of Comets

A typical comet observing report shown in Figure 1 shows the required observations in the format accepted (Green 1997) by the International Comet Quarterly (ICQ), and can be used as a basis for further discussion of the observing methodology:
- The designation of the comet is given in columns 4-9 for long period comets with the discovery year in columns 4-7, the discovery half month letter and numeral in columns 8 and 9. Periodic comets are designated with a numeral followed by a P to indicate the comet is periodic. So comet Halley is 1P, comet Borrelly is 19P, comet Mrkos is 124P and so on. There are 129 such numbered periodic comets. In the report format the number is given flush right in columns 1-3.
- The date of the observation is given in columns 12-24, with the year in columns 12-15, the month in columns 17-18 and the date to 0.01 UT in columns 20-24.
- The method used to determine the total magnitude of the comet is given as M in column 27. The codes are S=Sidgwick method (in-out method), B=Bobrovnikoff method (out-out method), or M=Morris method (modified out-out method). In the Sidgwick method the brightness of the in-focus comet is estimated against comparison stars which are defocused to appear the same size as the in-focus coma. The method is well suited to diffuse comets. In the Bobrovnikoff method the comet and stars are defocused by the same amount until they appear about equal size, and the out of focus images are

compared for brightness. The method is better suited to highly condensed comets. To overcome shortcomings in both methods, some observers prefer the Morris method, where the observer defocuses the comet just enough that the defocused disk is rather uniform in brightness, thereby removing the sharp brightness gradient present in many comets from outer coma to central condensation. Comparison stars are then defocused to the same apparent size and the brightness estimated in the same way.

- The total cometary magnitude (also referred to as m1, as opposed to the nuclear magnitude which is m2) determined as above is given in columns 28-33 with the decimal point in column 31. A fainter than estimate is shown with a left bracket in column 28, and if the estimate is approximate or made under poor conditions a colon is placed in column 33.
- The reference source (r) for the comparison stars used for the magnitude estimate is given in columns 34-35. There is an extensive list of such accepted references which must be consulted.
- The aperture of the instrument used for the observation is given to 0.1cm in columns 36-40, the type of instrument in column 41, the focal ratio as a whole integer in columns 42-43 and the magnification flush right in columns 44-47.
- The observed coma diameter in arc minutes is given in columns 49-54.
- The Degree of condensation of the coma, DC, is recorded in columns 56-57. DC is measured on a scale of 0-9, with 0 representing a diffuse coma with no sign of any condensation, and 9 representing a sharp disk or star-like coma without any sign of diffuseness. The estimate is made visually by comparing the appearance of the coma with the scale shown in figure 2. If the observer estimates the DC as being between two values such as 4-5, then the estimate is recorded with a / following the lower value, such as 4/.
- The tail length is given in columns 59-64 to an accuracy of 0.01º if possible. For short tails the value may be given in arc minutes or seconds, inserting an 'm' or 's' in column 64 to indicate the scale used.
- The position angle of the tail is given in columns 65-67. The angle is measured eastwards of north, with north being 0º, east 90º, south 180º and so on.
- Finally, the identity of the observer is given in columns 76-80 using accepted ICQ codes.

The foregoing notes are a rather brief description of the actual reported data. From this one can derive the important visual data of total cometary brightness, coma size, condensation, tail length and position angle.

3. Results on a selection of Comets

Observations have been made on over 40 individual comets, ranging from those with only a single observation, to well-observed comets like comet Hale-Bopp, for which 375 separate observations were recorded. A selection of results are shown in Figures 3-6.

C/1995 O1 Hale-Bopp

The observations of comet Hale-Bopp (Cooper 2001) represent the most complete series of data ever obtained by ASSA members. This is probably due to the discovery nearly 2 years before perihelion, and the bright nature of the comet which resulted in easy naked eye visibility. For any comet, visual brightness estimates can be plotted against time to produce a light curve depicting the comets behaviour. The light curve for comet Hale-Bopp commences shortly after discovery in July 1995 at magnitude 11, followed by a slow increase to magnitude 8, and then a more rapid increase to magnitude 5.5 by August 1996. When the rapid increase halted at this time astronomers started to revise their peak brightness downwards. However, it appears that the formation of water vapour, which is the primary driver for a comets brightness when near the sun, occurred later than predicted, and the rapid increase resumed in late 1996. At this time the comet was too far north for observation from southern Africa, hence the gap in the light curve. Comet Hale-Bopp was recovered from the southern hemisphere in April 1997, peaking at magnitude -0.3. The comet showed a regular decrease in brightness after perihelion.

The degree of condensation over the same observation period is shown in Figure 3. At discovery the DC was 2-3, increasing to a sharpish coma of DC=8 just after perihelion. It is normal for the results to show considerable scatter, which depends on the observer, observing conditions and type and size of instrument used. What is important is the trend of the averaged measurements.

Finally, the tail length and position angle are also shown in Figure 3. While comet Hale-Bopp was a bright comet, it did not grow a long tail due the viewing geometry. A short tail became evident in late 1995, growing to 1.3 degrees in late 1996 when the comet entered the solar glare. In April 1997 the comet sported a bright, curved dust tail of about 3°.

C/1998 J1 SOHO

The results for this comet (Cooper 1998) are shown in Figure 4. This comet was discovered by the Solar and Heliospheric Satellite (SOHO) on 1998 May 3. The satellite normally detects sungrazing comets in the last days before they crash into the sun, but based on a crude set of positional measurements it was realized that this comet would miss the sun, becoming possibly a naked eye object in the early evening sky. The first ASSA observations were on May 16-18 with an estimated visual magnitude of 2-3. The brightness declined rapidly thereafter as the comet moved away from its close encounter with the sun, and had faded to magnitude 9 by the first week of July. The comet underwent an outburst on June 1, lasting a couple of days, brightening from magnitude 5 to 3.5.

Initially the comet displayed a very sharp coma of DC=8-9, but decreasing regularly as the comet receded from the sun, being a spurious patch of DC=1 just 50 days later. Comet SOHO also displayed a very distinctive sharp tail, which could be traced for about 5.5° at its longest on 1998 May 23.

C/2001 A2 LINEAR

This comet was discovered by the Lincoln Near Earth Asteroid Research team in mid January 2001 (Cooper et al 2002). It was around magnitude 19 at the time, and predicted to become as bright as magnitude 9 in 2001 June. However, in late March the comet underwent a major increase in brightness from around magnitude 11 to 7.5. Images of the comet taken with the Catalina 1.54m reflector on April 30 showed the nucleus had split into two, the highly condensed fragments of roughly equal brightness separated by 3.5" and aligned precisely on an east-west line. Previous observations using the same telescope had shown a single nucleus on April 24. Analysis of the separation of the fragments indicate that the initial splitting of the nucleus occurred on March 29.9 ± 1.6 UT, which coincides with the increase in brightness of the comet.

The results of observation by ASSA members are shown in Figure 5. The first ASSA observation was made on 2001 April 1.74, less than 2 days after the presumed initial splitting of the nucleus, with the comet at visual magnitude 8.4. The comet continued to brighten rapidly during April, and by month end was at magnitude 6. The light curve in Figure 5 shows a steady increase in brightness, with a possible outburst around April 28 (a single observation) and a definite surge around May 24/25, when the brightness increased to magnitude 4.5 before declining again to magnitude 5.2. This date coincides with the date of perihelion (distance from sun 0.78 AU). Shortly afterwards, the comet, up to this stage an evening object, became lost in the solar glare. It was recovered Cooper on June 16 in the early morning sky at magnitude 3.8, an easy naked eye object, sporting a tail just over 1 degree long.

After perihelion, the brightness continued to increase, peaking at magnitude 3.7 on about June 19. Closest approach to earth (0.24 AU) occurred on July 1 by which time the comet had faded to magnitude 5. Observations continued until the comet faded from view during August.

Regarding size, the coma extended around 3-5 arc minutes during its early evening apparition, rising to almost 10 arc minutes before being lost in the solar glare. After perihelion, the coma size continued to increase, and reached a peak, as expected around closest approach to earth, of about 20 arc minutes. The degree of condensation of the coma increased from around 3 when first observed to a maximum of around 7, coinciding with date of perihelion. The coma became less condensed after perihelion rather more rapidly than the increase in condensation.

C/2000 WM1 LINEAR

This Linear comet was discovered (Shanklin 2001) on 2000 December 16 and originally reported as asteroidal and magnitude 18. On December 20 observations by Spahr showed the object to be cometary, with a short broad tail. It was predicted that the new comet, whose orbit indicated it was not a first time arrival from the Oort Cloud, might brighten to magnitude 4. The comet was first observed by ASSA members on 2001 October 26 when it was magnitude 10.8. In November a rapid brightening to magnitude 6 occurred, and the comet remained this bright until being lost in sunlight in 2002 January. The comet became a fine bright object when it was recovered later in January in the morning sky, at magnitude 2.3. Thereafter the comet declined regularly in brightness as it receded from the sun and was observed until 2002 April. The results are shown in Figure 6.

4. Methodology of Meteor Observations

As with comets, meteors can be observed visually, and instrumentally using radio, radar, photography and video imaging. While Graham Poole uses a radar facility from Grahamstown, all other results so far have been through visual work. There are two main disciplines; counting and plotting. By counting meteors from known streams over as many nights as possible while a stream is active we can generate an activity profile for the stream. Plotting is used for analysis of minor stream activity and for closer scrutiny of radiant size and structure in all meteor streams. However, when the objective is to measure the peak rates of major streams, plotting is abandoned in favour of straight counting.

The most simplistic representation of a meteor rate would be to count the number of shower meteors observed and divide this by the observing time to give a rate per hour:

$$\text{Rate} = N/T \qquad (1)$$

However, this crude calculation does not take into account the conditions under which the observations were made. Hence the zenithal hourly rate is calculated by the formula:

$$\text{ZHR} = \frac{N \times F \times r^{(6.5-LM)}}{T_{eff} \times \sin h \times c_p} \qquad (2)$$

where:
- N = number of shower meteors observed
- F = factor correcting for obscuration by clouds, trees etc.
- r = population index
- h = mean altitude of radiant above horizon
- LM = limiting magnitude
- Teff= observing time in hours corrected for breaks
- c_p = observer perception coefficient

The population index, r, which is a measure of the increase in meteor frequency from one magnitude to the next fainter magnitude, is determined from the reported magnitude distribution of the meteors. It is normal also to correct the rate for the observers perception coefficient, c_p, which is determined from the magnitude distribution of observed sporadic meteors. To be of use, a meteor watch must also be calibrated for seeing conditions. We do this by measuring the limiting magnitude at the start and end of each period, and more often if conditions change rapidly. The limiting magnitude is defined as the faintest star seen in the watch area using averted vision. In general, it is normal to disregard observations made when the radiant is below 15° and when the limiting magnitude of the watch is below magnitude 5.0. The error for each watch is determined according to the formula:

$$\Delta ZHR = ZHR / \sqrt{N} \qquad (3)$$

In meteor plotting, all of the information is recorded as for a count, but the path of the observed meteor is plotted on a map drawn in gnomonic projection. The finished plots are analysed later to determine radiant activity, position and structure. Some activity profiles and plots determined using this methodology will be discussed below.

5. Results on some Meteor work

Eta Aquarids

Comet Halley (1P) is the parent body of two observable meteor showers. The Orionids visible in October are the inbound particles from the stream, and the eta Aquarids visible in late April and early May are the outward portion of the stream. With a radiant on the celestial equator and activity at maximum of about 50/hour the eta Aquarids are the most active southern shower. South Africa has a history of observation of this shower extending back to Tupman (Cooper 1996a), and nowadays is observed almost every year from here weather permitting.

Cooper published a review of eta Aquarid activity during the period 1986 to 1995 in the International Meteor Organisation journal (Cooper1996b). These results were based on South African observations and selected overseas observers who had observed the shower on regular occasions. Some determined activity profiles are shown in Figure 7. These indicate activity from the shower from at least April 19 to May 20, with a maximum of typically 60/hour at solar longitude 43.5-44.0°, normally corresponding to May 5 or 6. Heightened activity very often continues for several days after the primary maximum. Analysis of the meteors shows the average brightness to be 2.4, with bright members common. These show a high tendency to leave persistent trains, often lime green in colour. Overall 32% of eta Aquarids leave trains, rising to over 3 out of 4 for Aquarids of magnitude 1 or brighter.

April Lyrids
Similar to the IMO article on the eta Aquarids, Dubietis and Arlt (2001) published a review of the April Lyrids from 1988 to 2000. These results included observations from Cooper and Streicher. The shower is associated with comet Thatcher C/1861 G1, which has an orbital period of 415 years. The activity profiles for 1998 to 2000 are shown in Figure 8. These indicate the shower maximum occurs between solar longitude 32.0-32.4 and is typically 15-20 Lyrids per hour.

Virginids
The IMO has in the past run a campaign to observe the Virginids (McBeath 1992), a complex set of radiants active in Virgo and Leo from February to April, and responsible for a high proportion of fireballs reported in this period. This program continues, though the only South African currently engaged in the program is the author. More observers are required. The process involves plotting all meteors seen on specially prepared gnomonic charts and logging their characteristics in order to analyse and determine possible centres of activity over the months February to April. Several potential radiants, which showed activity in the original IMO study, have been identified. A sample plotting input is shown in Figure 9.

Geminids
The Geminids, though strictly speaking a northern shower, remain one of the most reliable active showers which reward observation from here too. Their observation is somewhat subject to the unstable summer weather at this time, but in 1999 for example they were well observed from South Africa (Cooper 2000a). Several observers logged over 40 hours on the peak nights, seeing a peak rate of 85/hour on the night of December 14/15. The stream is also well known for its mass sorting, with the earth intercepting larger particles later in the stream. This was well seen in the magnitude distribution, with average Geminid magnitudes of 1.90 on December 12/13, 1.88 on December 13/14 and 1.30 on December 14/15.

Leonids
The parent body of the Leonids is comet Tempel-Tuttle 55P, which orbits the sun once every 33 years. With its return to perihelion in 1998, expectations were high for potential storm rates from 1998 onwards. South Africa is never well placed to observe the shower since the radiant is only high enough for observation from about 2 am local time until about 4 am when dawn breaks. The last few years have also seen adverse weather conditions, which have affected observations on all the years from 1998 to 2001. Nevertheless, we have managed to secure some important observations from this part of the world. Observers in 1998 (Cooper 1999) were taken by surprise by the appearance of scores of very bright Leonid fireballs on the morning of November 17. In 1999 the peak occurred just after 02h00 UT and South Africa was well placed to catch the rise.

Observations by those observers who did manage to avoid the clouds show corrected rates of about 500/hour just before twilight on November 18 (Cooper 2000b). The activity profile for the night is shown as Figure 10.

6. Future Observing Progams

I have shown a sprinkling of results of comets and meteors based on visual observations. There is a wide scope for observers using wider techniques, for which I would like to encourage programs to be started. The International comet Quarterly has requested CCD photometry of faint southern comets to supplement observations being made from the northern hemisphere. Comet searching and discovery is another field that is being neglected from Southern Africa, the last comet discovery having been in 1978. NASa's Dr Peter Jenniskens has requested a program of radio monitoring of meteors. Similarly the IMO encourages the video monitoring of meteors. Finally, double station photography of fireballs in order to determine orbital characteristics needs to be carried out. All these techniques are fully operational in many other countries, and all that South Africa requires is a number of dedicated observers to follow suit.

7. Conclusions

The foregoing discussion shows the methodology required to observe comets and meteors visually, and provides examples applied to four comets and five meteor showers. It is readily accepted that in these modern times there are factors mitigating against going out and observing – atmospheric pollution, particularly in winter, lethargy, security, and increased light pollution all show there effects over time. However, we in southern Africa are still blessed with skies and weather unlike most other countries, who continue to churn out observations under worse conditions than we have. More observers are encouraged to take up the valuable activity of observing comets and meteors.

8. References

Cooper 1996a, T.P. The rate profile of the eta Aquarid meteor stream, MNASSA Vol.55, p130, October 1996. Paper presented at the 3rd ASSA Symposium.

Cooper 1996b, T.P. A Decade of Visual eta Aquarid Meteor Observations, WGN, The Journal of the IMO, 24:5, p157, October 1996.

Cooper 1998, T.P. ASSA Observations of Comet SOHO C/1998 J1, MNASSA Vol.57, p58, October 1998.

Cooper 1999, T.P. The Summarised Southern African Observations of the 1998 Leonids, MNASSA Vol.58, p22, April 1999

Cooper 2000a, T.P. Observations of the Geminids in 1999, MNASSA Vol.59, P45, June 2000.

Cooper 2000b, T.P. ASSA Observations of the 1999 Leonid Meteor Shower, MNASSA Vol.59, p20, April 2000

Cooper 2001, T.P. The Comet Hale-Bopp Album, ASSA observations, 2001

Cooper et al 2002, Cooper T.P, Pringle-Wood D, Begbie, M, Hollenbach, W, ASSA

Observations of comet Linear C/2001 A2, MNASSA Vol.61, p6, February 2002.
Dubietis and Arlt 2001, A, and R, Thirteen Years of Lyrids from 1988 to 2000, WGN, the Journal of the IMO, 29:4, p119, August 2001
Green 1997, D.W. Guide to Observing Comets, Special Issue of International Comet Quarterly, January 1997
McBeath 1992, A, WGN, Journal of the IMO, 20:6, p226, 1992
Shanklin 2001, J, The Comet's Tale, Newsletter of the BAA, 2001 April p20