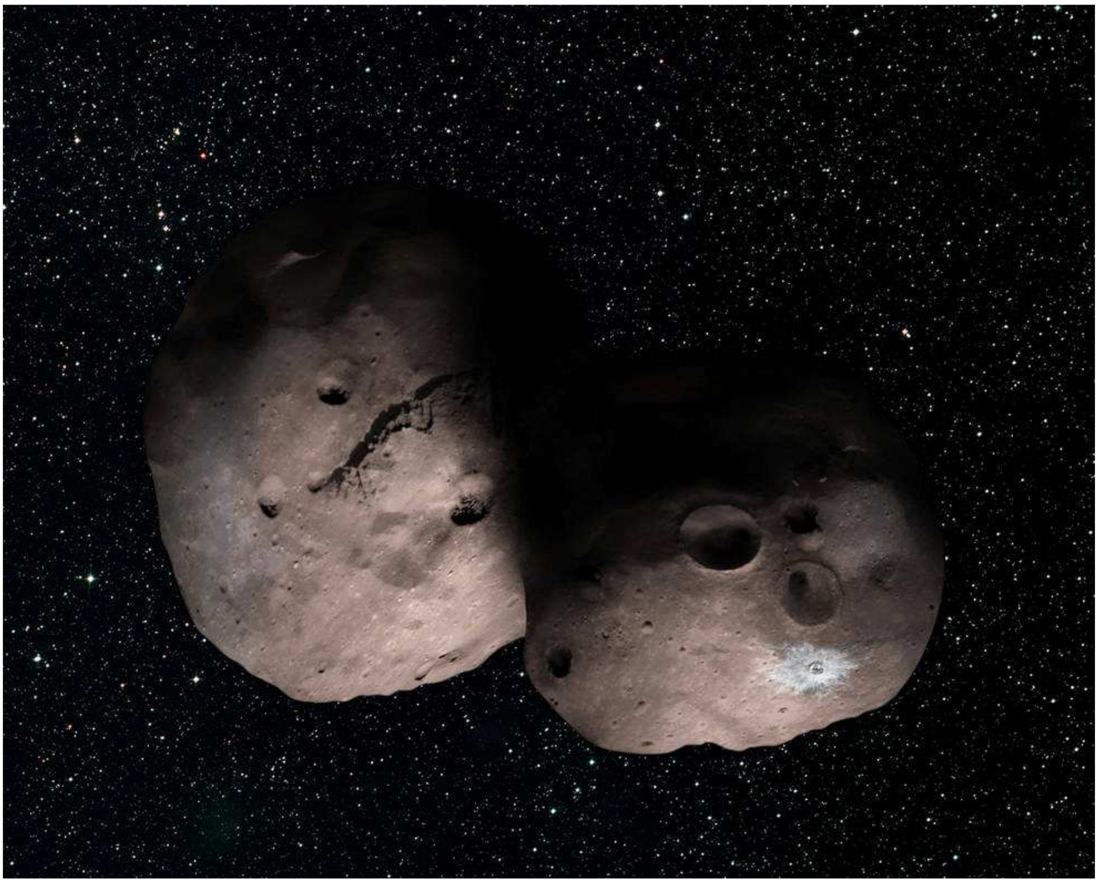
ISSN 0024-8266

mnassa

monthly notes of the astronomical society of southern africa

Volume 76 Nos 9 & 10 October 2017



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Cover Photo:
An artist's concept of 2014MU69. See page 214. Credits NASAJHUAPLSwRIAlex Parker

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News Note: First Gravitational Waves from an Identified Object

The first successful detection of gravitational waves was on 11 February 2015, by the LIGO group in the USA, and the source was inferred to be the merger of two orbiting black holes of 29 and 36 solar masses (See *MNASSA* **75**, 1, 2016). However, the precise place of origin on the sky could not be identified by any kind of electromagnetic detector, whether in x-rays, visible light or radio. The direction from which these waves were arriving was only very roughly known and no obvious source could be detected by any kind of sky monitor. Any radiation other than gravitational was either too weak or obscured.

A spectacular result has now been reported. The LIGO network, joined recently by the Advanced Virgo detector in Italy, made public on 16 October 2017 that they had detected an event (on 12 August 2017) resulting from the merger of two neutron stars. The signal was a kind of gravitational "chirp", rising in frequency from a few tens of cycles per second to thousands per second, lasting for about 100 seconds altogether. This was interpreted as the death spiral of two neutron stars spinning faster and faster as they merged.

This time, however, thanks to the additional detector, the gravitational event could be triangulated and localized within 30 square degrees. In addition, it was found to have been accompanied in time by a gamma-ray burst observed by the Fermi space telescope, though from what part of the sky the gamma rays came could not be specified precisely. Nevertheless, the data were good enough to trigger visible-light searches of likely galaxies in the area. Very soon it was found that an apparent nova-like event had occurred in the outskirts of the galaxy NGC4993. As many as 70 observatories made observations of this object. One of the first to take a spectrum was SAAO (see separate News Note).

Below is the abstract of the main paper announcing the result, from *Physical Review Letters*. The number of co-authors runs into thousands. Many more papers have already been published or are in press.

PRL **119**, 161101 (2017) PHYSICAL REVIEW LETTERS 20 OCTOBER 2017

GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral

B. P. Abbott *et al.**
(LIGO Scientific Collaboration and Virgo Collaboration)
(Received 26 September 2017; revised manuscript received 2 October 2017; published 16 October 2017)

On August 17, 2017 at 12:41:04 UTC the Advanced LIGO and Advanced Virgo gravitational-wave detectors made their first observation of a binary neutron star inspiral. The signal, GW170817, was detected with a combined signal-to-noise ratio of 32.4 and a false-alarm-rate estimate of less than one per 8.0×10^4 years. We infer the component masses of the binary to be between 0.86 and 2.26 $M_\odot$, in agreement with masses of known neutron stars. Restricting the component spins to the range inferred in binary neutron stars, we find the component masses to be in the range 1.17–1.60 $M_\odot$, with the total mass of the system $2.74^{+0.04}_{-0.01} M_\odot$. The source was localized within a sky region of 28 deg^2 (90% probability) and had a luminosity distance of 40^{+8}_{-14} Mpc, the closest and most precisely localized gravitational-wave signal yet. The association with the γ-ray burst GRB 170817A, detected by Fermi-GBM 1.7 s after the coalescence, corroborates the hypothesis of a neutron star merger and provides the first direct evidence of a link between these mergers and short γ-ray bursts. Subsequent identification of transient counterparts across the electromagnetic spectrum in the same location further supports the interpretation of this event as a neutron star merger. This unprecedented joint gravitational and electromagnetic observation provides insight into astrophysics, dense matter, gravitation, and cosmology.

Note: News Gravitational Wave Discovery

Extract from the Press briefing at the SAAO – 16 October, 2107.

The South African Astronomical Observatory (SAAO) and the Southern African Large Telescope (SALT) are among the 70 ground- and space-based observatories that observed the cataclysmic explosion of two colliding neutron stars, immediately after their gravitational shock waves were detected by the U.S.-based Laser Interferometer Gravitational-Wave Observatory (LIGO) and the European-based Virgo detector.

The discovery, on 18 August, 2017 marks the birth of a new era in astrophysics, the first cosmic event observed in both gravitational waves and light. SALT and other SAAO telescopes have provided some of the very first data in what is turning out to be one of the most-studied astrophysical events ever.

In this particular event, dubbed GW170817, two neutron stars spiralled inwards and then collided, emitting gravitational waves that was detectable for about 100 seconds. Theorists have predicted that such a collision also results in a ***kilonova*** explosion of light, initially in the form of gamma rays which were detected by space-based telescopes. The gamma rays were then followed by X-rays, ultraviolet, optical, infrared, and radio waves. The light-based observations from other large international telescopes show that heavy elements, such as lead and gold, are created in these collisions and subsequently distributed throughout the universe - confirming the theory that a major source for the creation of elements heavier than iron does, indeed, results from these neutron star mergers.

South African activities also included the first observations contributing to published scientific results by the MeerKAT radio telescope under construction in the Karoo.

It was decided to drop all other plans for that evening, and go for a spectral observation with SALT, since a large telescope is needed for such observations. It was a difficult observation since everything had to be dropped to do it in twilight, before it got properly dark. SALT was only the third observatory to provide a spectrum of the target, and the first spectrum that clearly started showing anomalous behaviour proving that this was no run-of-the-mill transient event.

The significance of getting early observations stems from the afterglow of the collision changing very rapidly. Piecing together the new science from the event requires combining observations spanning the first hours, days and weeks after the merger. The first SALT spectrum has a very prestigious spot in the combined scientific paper, with thousands of authors and hundreds of institutions. In addition, several, more detailed scientific papers have also been written based on SALT, SAAO and other Sutherland observations.

The early SALT observations showed that the explosion was relatively bright and blue. Only two or three days later, further observations by SALT, SAAO, MASTER (joint Russian-South African optical telescope) and IRSF (Infra-Red Survey Facility; joint Japanese-South African infrared telescope), both in Sutherland and other major international telescopes showed that the light was rapidly fading and turning red, due to the dusty debris blocking the bluer light, as predicted by the theory of the evolution of a kilonova explosion.

The results of this unprecedented event have demonstrated the importance of collaborative multi-messenger observations and mark a new era in astronomy. "The ability of SALT and SAAO telescopes to respond rapidly to unexpected discoveries is a major reason for the success of these observations and will ensure similar successes in the future", says Dr Stephen Potter, Head of Astronomy at the SAAO. "We are very proud to have played a major role in such a historical event thanks to the sterling efforts and expertise of SAAO and SALT staff that ensure that our observatory is at the forefront of world-class scientific endeavours."

News note: Nobel Prize in Physics awarded for Gravitational Wave Discovery

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2017 with one half to Rainer Weiss LIGO/VIRGO

Collaboration and the other half jointly to Barry C. Barish LIGO/VIRGO Collaboration and Kip S. Thorne LIGO/VIRGO Collaboration *"for decisive contributions to the LIGO detector and the observation of gravitational waves"*

Gravitational waves finally captured

On 14 September 2015, the universe's gravitational waves were observed for the very first time. The waves, which were predicted by Albert Einstein a hundred years ago, came from a collision between two black holes. It took 1.3 billion years for the waves to arrive at the LIGO detector in the USA.

The signal was extremely weak when it reached Earth, but is already promising a revolution in astrophysics. Gravitational waves are an entirely new way of observing the most violent events in space and testing the limits of our knowledge.

LIGO, the Laser Interferometer Gravitational-Wave Observatory, is a collaborative project with over one thousand researchers from more than twenty countries. Together, they have realised a vision that is almost fifty years old. The 2017 Nobel Laureates have, with their enthusiasm and determination, each been invaluable to the success of LIGO. Pioneers Rainer Weiss and Kip S. Thorne, together with Barry C. Barish, the scientist and leader who brought the project to completion, ensured that four decades of effort led to gravitational waves finally being observed.

In the mid-1970s, Rainer Weiss had already analysed possible sources of background noise that would disturb measurements, and had also designed a detector, a laser-based interferometer, which would overcome this noise. Early on, both Kip Thorne and Rainer Weiss were firmly convinced that gravitational waves could be detected and bring about a revolution in our knowledge of the universe.

Gravitational waves spread at the speed of light, filling the universe, as Albert Einstein described in his general theory of relativity. They are always created when a mass accelerates, like when an ice-skater pirouettes or a pair of black holes rotate around each other. Einstein was convinced it would never be possible to measure them. The LIGO project's achievement was using a pair of gigantic laser interferometers to measure a change thousands of times smaller than an atomic nucleus, as the gravitational wave passed the Earth.

So far all sorts of electromagnetic radiation and particles, such as cosmic rays or neutrinos, have been used to explore the universe. However, gravitational waves are direct testimony to disruptions in spacetime itself. This is something completely new and different, opening up unseen worlds. A wealth of discoveries awaits those who succeed in capturing the waves and interpreting their message.

(Royal Swedish Academy 3 October 2017)

News Note: 2017 Astronomy Town Meeting

The now annual "Town Meeting" provides a general overview especially of government thinking concerning astronomy in South Africa. It is also one of the few occasions when astronomers with different specialities can meet each other. This one was held 20-21 October 2017 at the Iziko Planetarium so that delegates could witness a show with the new digital projector. What follows are some hastily-taken notes of certain of the talks.

Dr Thomas auf der Heyde, Deputy Director of the Dept of Science and Technology spoke about the problem that the science budget is not receiving annual increases. It is desirable that the community should be politically aware and should make government aware of the societal benefits of their activities. The SKA project has created 7 000 jobs and has spent R134m on local suppliers. It is also providing benefits to Carnarvon, such as technical training, improvements to the local school and bursaries. It is also desirable to tie in projects with BRICS initiatives whenever possible. The department is keen to push multi-wavelength projects. The government intends to establish a National Astronomy Institute, following its combination of the radio astronomy activities into the National Radio Astronomical Observatory (NARAO) earlier this year. He emphasized how the problems of inequality, poverty and unemployment are major issues and that we have to think how these may be addressed in doing science. “Transformation is an imperative” he said, drawing attention to the predominantly white colour of the audience members.

The Astronomy Advisory Council acts as an intermediary to the NRF. R Kraan-Korteweg is chairperson. It includes Kechil Kirkham of the Space Advisory Company, an active member of ASSA

A spokesman for SKA mentioned that an International intergovernmental organization is to be set up. The SA SKA will have 200 dishes including MeerKAT. MeerKAT will run for 5 years as an SA operation before becoming part of SKA. All 64 antennas have been mounted. Of these, 56 have been handed over by the contractors.

HERA will consist of 350 14-m transit elements. 52 have been constructed and 75 will be finished by end 2017.

Ted Williams spoke of SAAO progress. He mentioned the new 1m Lesedi telescope which has a low resolution spectrograph and will receive a wide-angle camera next year. The Meerlicht telescope will have a 1.65-degree square field for making simultaneous observations with MeerKAT. A number of new projects are under way – WALOP polarization survey, PRIME near-IR telescope (Japan), ATLAS asteroid detector (NASA), upgrade to Giraffe instrument, Remote operation of SAAO telescopes and the Las Cumbres high resolution spectrograph.

Petri Vaisanen spoke of the productivity of SALT and suggested new fields that could be concentrated on such as the baryon cycle and a spectrograph for low surface-brightness objects. Transient and time-domain astronomy is a strong point locally.

Sergio Colafrancesco: The next-generation Cherenkov telescopes (CTA) will be built at ESO-Chile and La Palma (Spain, Canary Islands) with its Data Management Centre in Berlin and headquarters in Bologna. This was in spite of a strong bid by Southern African interests. HESS in Namibia will remain the most sensitive gamma ray telescope of its kind until 2022. The CTA project requires €400M; at present they have €250M lined up.

Gaboille Madeba spoke on Human Capacity Development – WISA Awards for Women in Science to increase representation and various plans such as a National Astronomy Week biannually in April. Increase in outreach activities such as workshops, exhibitions, visits to facilities, mentoring. She was worried that only 25% of the population know of the SKA. Also wants to promote “Astronomy Days”, stargazing, braais, videos…

Claude Carignan spoke on cooperation with FAST (the 500m radio telescope dish in a valley in China) and possible syntheses with MeerKAT for pulsar searches, HI intensity mapping and Cosmic magnetism. He spoke of papers resulting from KAT-7 including a “cosmic fountain” in NGC253.

Many opportunities exist for international cooperation – SA-EU Framework proposals, Radio Net (Access to various European radio facilities), JIVE (Joint Institute for VLBI (ERIC)) etc.

At one point it was suggested that the BRICS astronomers should have a journal of heir own. This was opposed by various audience members who pointed out that such a medium would require many years to acquire a significant reputation. We should continue to aim to publish in well-known international journals.

Lerothodi Leeuw spoke on the Astro Particle Physics International Forum – an OECD initiative. There had been a conference in India of BRICS science agencies in September, looking for possible large joint projects where partnerships from at least three countries were encouraged to put forward ideas for projects.

Yin-Zhe Ma presented information on the Chinese astronomical communities and current developments. Some five other countries have bilateral agreements with South Africa that offer opportunities for scientific collaborations.

Ian Glass summarized recent initiatives in South African astronomical history, including preparation for the 200th anniversary of the SAAO/Royal Observatory in Cape Town and the need to preserve archives. Current projects such as SALT and SKA also need to keep archival records of their activities.

Sivuile Manxoyi gave an interesting account of how traditional beliefs about the stars and heavenly bodies can be used to encourage interest in modern scientific astronomy. He pleaded for more material to be made available in languages other than English. He described a very successful outreach effort aimed at the Afrikaans-speaking community in Sutherland. He also praised the outreach efforts of Auke Slotegraaf and others outside the professional community.

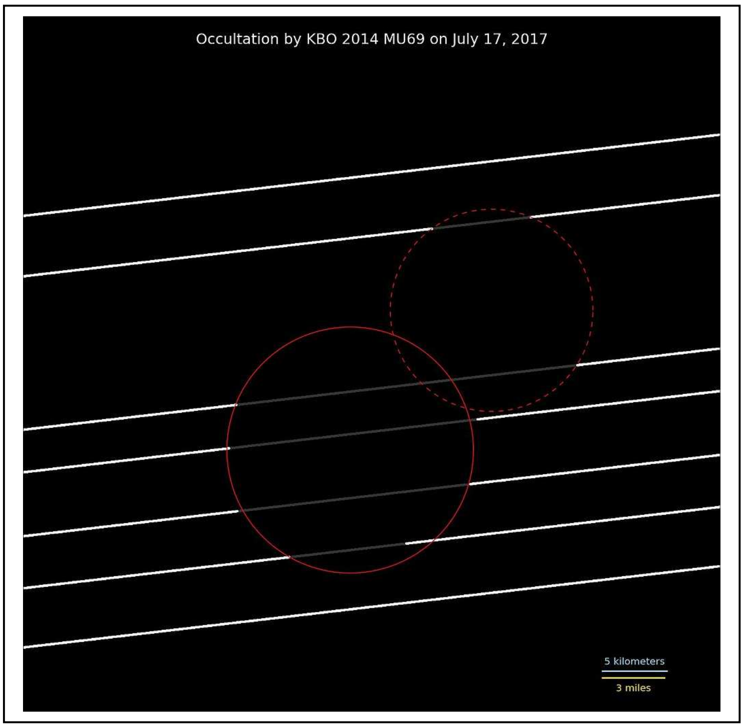
In summing up, Takalani Nemaungani mentioned that the Town Meetings seemed to be becoming annual events. He was somewhat critical of the fact that there was no professional Astronomical Society as in other countries. However, this need has been satisfied in recent years by the SA Institute of Physics.

It was unfortunate that the SKA and the upper echelons of the Department of Science and Technology and the NRF were conspicuous by their absence. The elephants were not in the room, one might say. (ISG)

2014 UM69

Case Rijsdijk

This is a brief note to conclude the results of the occultation of a star by the asteroid 2014 MU69; arguably the most difficult occultation ever observed.



The occultation was described in previous editions of MNASSA[1,2]. Of the twenty-four 16-inch telescopes used, 5 actually recorded the occultation as shown in *Fig. 1 (left).*

The telescopes were placed between 10 and 20 km apart in a N-S line, normal to the path of the occultation, in a remote region of Chubut and Santa Cruz, Argentina. Fig. 1 shows seven of the central lines of light from the star broken by MU 69 as it occulted the star.

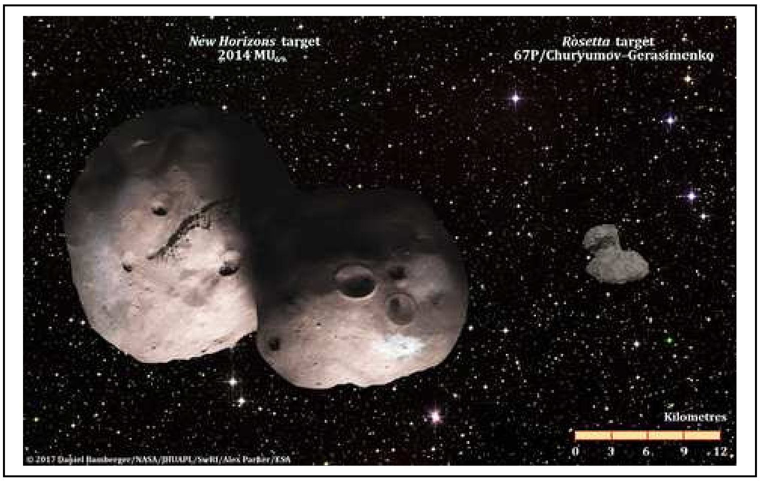


Fig 2 (left). See text for description

A considerable amount of fiddling and modelling was then done to see what as to what shape could produce the results obtained. It could either be a sort of lopsided ellipsoid, similar to, but larger than the Rosetta or be it a binary, as shown in Fig. 2 with Rosetta for comparison.

2014 MU69's shadow traces its most likely binary shape, as seen in the stellar occultation that occurred over Argentina on 17 July 2017. The best-fit red circles reveal MU69's possible doubled-lobed – or binary – nature

1 *MNASSA* Vol **76**, Nos 5 & 6, June 2107
2 *MNASSA* Vol **76**, Nos 7 & 8, August 2107

The real meaning of magnitude per square arc-second

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Director Cosmology Section ASSA

Intuitively, observing faint objects with low surface brightness against a bright sky will be difficult. In order to achieve some kind of metric, amateur astronomers frequently quote sky brightness in terms of magnitude per square arc-second (mpsas). A very good night sky will have a brightness of 21.8 mpsas or greater while inner-cities are subjected to 15 mpsas rendering all but the brightest stars invisible.

In conversation, the editor of this journal asked "…but what is it?"

We'll start with how stellar magnitudes are defined. In short, they are a logarithmic scale which – apart for slight corrections - uses Vega as a zero reference. In the visible part of the spectrum, Vega's emission corresponds to a black body with a surface temperature near 11 000 kelvin. The received energy per photometric band is given by Bessel 1979 [1]. An alternate set of measurements are presented in Bessel 1990 [2].

	Bessel (1979)		
Photometric Band	**Effective wavelength**	**FWHM Bandwidth**	**Mag zero flux**
	nm	$d\lambda/\lambda_0$	Jy
U	360	0.15	1810
B	440	0.22	4260
V	550	0.16	3640
R	640	0.23	3080
I	790	0.19	2550

The Jansky (Jy) is a curious unit that's normally used in radio astronomy. This identity quoted by Wirth & Huchra [3] can be useful

$$1\,\text{Jansky} = 1.51\times10^{7}\,\frac{\text{photons}}{\text{sec}}\times\frac{1}{\text{m}^2}\times\left(\frac{d\lambda}{\lambda_0}\right)^{-1} \qquad (0.1)$$

As an example

Suppose we're interested in the B-band flux at the top of the atmosphere coming from a 17.3 magnitude star. We can calculate it directly

$$\begin{aligned}\text{Flux} &= 10^{-0.4\times17.3}\times4260\,\text{Jy}\\ &= 5.12\times10^{-4}\,\text{Jy}\\ &= 5.12\times10^{-4}\times1.51\times10^{7}\times0.22 \qquad (0.2)\\ &= 1700\left(\frac{\text{photons}}{\text{sec}}\times\frac{1}{\text{m}^2}\right)\end{aligned}$$

So what is it really

We're considering visible photons, so let's calculate the number of V-band photons corresponding to 21.8 mpsas. Each square arc-second of the sky will deliver

$$\begin{aligned}\text{Flux} &= 10^{-0.4\times21.8}\times3640\,\text{Jy}\\ &= 6.94\times10^{-4}\,\text{Jy}\\ &= 6.94\times10^{-4}\times1.51\times10^{7}\times0.16 \qquad (0.3)\\ &= 16.8\left(\frac{\text{photons}}{\text{sec}}\times\frac{1}{\text{m}^2}\right)\end{aligned}$$

This is (barely) detectable to the dark adapted eye, let's assume the eye is dilated to 6.5 mm and the visual acuity is a disc ~2 arc-minutes in diameter. This means the eye is responding to about 6.3 photons per second. Quite astonishing.

The manufacturers of a popular *Sky Quality Meter* supply this expression [4]

$$\text{Illuminance} = 1.08 \times 10^{5-0.4\times\text{mpsas}} \left(\frac{\text{cd}}{\text{m}^2} \right) \qquad (0.4)$$

The candela is defined as a basic SI unit but it's effectively given by:

$$1\,\text{cd} = \frac{1}{683} \frac{\text{watt}}{\text{sr}} = 3.441 \times 10^{-14} \frac{\text{watt}}{\text{arcsec}^2} \qquad (0.5)$$

So that (1.4) can be re-written as:

$$\begin{aligned} \text{Illuminance} &= \frac{1.08 \times 10^5}{683} \times \frac{\text{sr}}{4.255 \times 10^{10}\text{arcsec}^2} \times 10^{-0.4\times\text{mpsas}} \\ &= 3.719 \times 10^{-9} \times 10^{0.4\times\text{mpsas}} \qquad (0.6) \\ &= 3.719 \times 10^{-9-0.4\times\text{mpsas}} \left(\frac{\text{watt}}{\text{m}^2\text{arcsec}^2} \right) \end{aligned}$$

So that for 21.8 magnitude skies, we get:

$$21.8\text{mpsas} \approx 0.709 \times 10^{-17} \frac{\text{watt}}{\text{m}^2} \frac{1}{\text{arcsec}^2} \qquad (0.7)$$

For comparison, Bessel's values give:

$$21.8\text{mpsas} \approx 0.607 \times 10^{-17} \frac{\text{watt}}{\text{m}^2} \frac{1}{\text{arcsec}^2}$$

This suggests that the Unihedron SQM-L exaggerates the mpsas measurement by $709/607 = 1.168 = 0.17$ magnitudes. The difference is consistent with the author's measurement of 21.97 mpsas (Leeuwenboschfontein, Karoo, 2016.12.30) and the Cerro Tololo Inter-American Observatory site's moonless measurement of 21.8 mpsas [5].

References

1. UBVRI Photometry II: The Cousins VRI system, Bessel, M. S., *PASP* 1979 vol **91** p 589 available from
http://iopscience.iop.org/article/10.1086/130542/pdf

2. UBVRI Passbands, Bessel, M. S., *PASP* 1990 vol **102** p 1181. Available from http://iopscience.iop.org/article/10.1086/132749/pdf

3. Wirth GD & Huchra, J, Astronomical Magnitude Systems, Harvard-Smithsonian CfA,
https://www.cfa.harvard.edu/~dfabricant/huchra/ay145/mags.html

4. Unihedron SQM Frequently Asked Questions – there's a calculator here http://unihedron.com/projects/darksky/magconv.php

5. CTIO / NOAO Newsletter No. 10 quoted in [3].

The bright bolide of 2017 June 15

Tim Cooper (Comet, Asteroid and Meteor specialist, Shallow Sky Section, ASSA)

Introduction

On the early morning of 15 June, 2017, as thousands of South Africans were on their way to work, a spectacular bolide was widely observed from the Eastern Cape, Kwazulu-Natal, Free State, Gauteng and Mpumalanga provinces. This event was the brightest since the super-bolide of 21 November, 2009 (Cooper 2011) and the Daytime Bolide of 12 March, 2013

(Cooper 2013), which had estimated total impact energies of 18.0 kT and 0.1 kT respectively (Chamberlin 2017). Reports of the brightness vary but the bolide probably peaked somewhere between magnitude -13 to -15, just too faint to be classified as a super-bolide (see Cooper 2017). This article summarises the bolide from the various eyewitness accounts received, all of which were followed up and analysed in order to determine the probable path across South Africa and a footprint for any possible meteorites that may have resulted if the bolide survived its passage through the atmosphere. All times are given in South African Standard Time (SAST).

Scope of visibility

The author investigated fifty separate eye witness accounts of visual sightings by members of the public, including two sequences of video footage of the bolide. The locations of all the reports were plotted in number sequence as received and are reproduced as Figure 1. The geographical spread in visibility ranged from as far south as Dordrecht, Eastern Cape to as far north as Dullstroom, Mpumalanga. Observers from Welkom and Richards Bay were able to observe the fireball as it travelled northwards respectively low above their eastern and western horizons, and those in the south eastern Free State saw the fireball travel above their heads moving in a north-north-easterly direction. Good reports were received from the Northern Drakensberg area, and it was also in this area that sounds associated with the meteor were heard. A large fraction of the sightings was from Gauteng, which witnessed the demise of the object to the south east, and a number of these sightings were useful to help define the northern limit of the visible meteor.

Important eye witness accounts

Those reports deemed to be of highest scientific value were investigated in detail, and the locations are shown in Figure 2. Hennie Pelser (location 41) was driving northwards on the R392 to Dordrecht. He saw the meteor high above to the right and behind the driver's side window, and disappeared behind the horizon in direction NNE. Duration was given as 3 seconds. This sighting was also the most southerly. While several reports are available which enable a determination of the end of the visible meteor, the entry point into the atmosphere could not be accurately ascertained. However Mr Pelser's report does indicate that the process of ablation had already commenced over the south-eastern Cape.

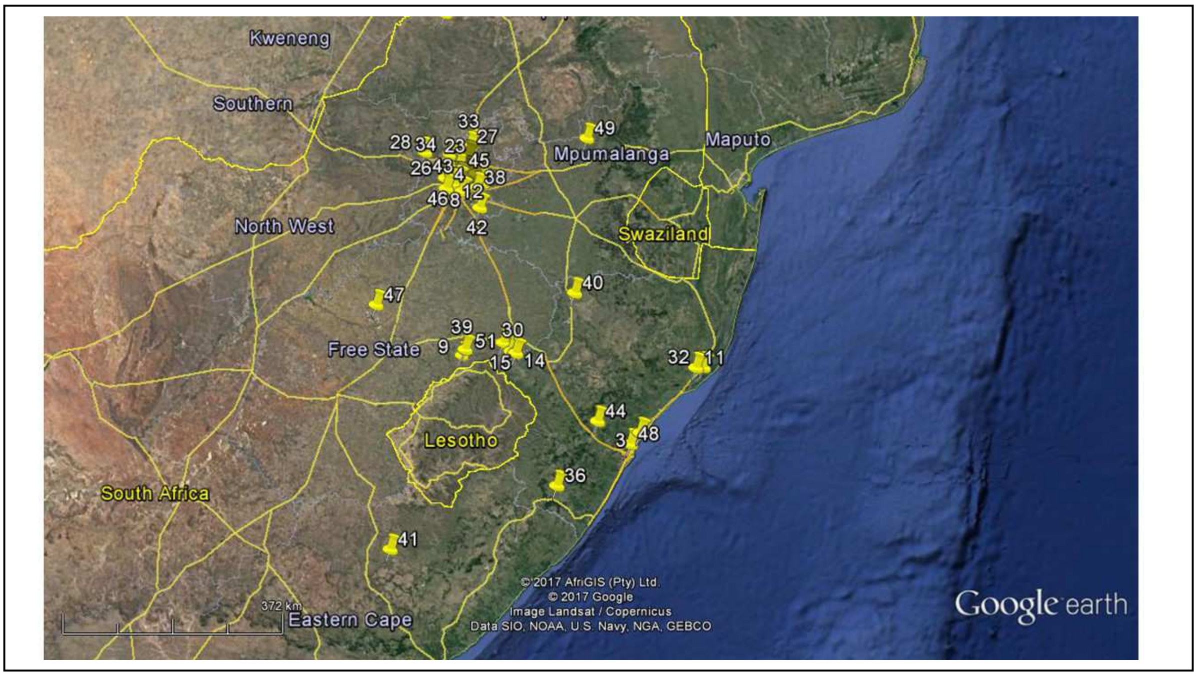

Fig 1. Locations of all 50 sighting reports. Numbers are in the sequence they were received. Due to congestion in Gauteng, not all numbered locations are visible.

Ronald Nair (36) was driving westwards on the N2, just after Harding and before the right hand turn onto R56 to Umzimkulu. The meteor was seen passing left to right about half way up the view in front of him. He described it as a huge ball of fire followed by flames which lit the dark sky, mostly yellow, but also orange and red.

Slightly further north in KZN, Warren Hale (44) was driving almost due west on the N3 at Woodlands, Pietermaritzburg. He first saw the meteor in azimuth 258°, which is north of location 41 and the point of entry into the atmosphere, and it disappeared behind a ridge at azimuth 320°. The meteor was visible for 3 seconds.

Fig 2. Locations of important reports, from which conclusions were arrived at to determine probable path (red arrow).

Letitia Veltman (9) was situated at Fouriesburg in the Free State, where she saw the meteor directly overhead and moving in direction NNE. The observation that the meteor passed overhead is an important pivot for the trajectory at this point.

Several useful reports were obtained from the eastern Free State and KZN Drakensberg regions.

- Wiseman Kurauone (30) was standing alongside the D119 at the turn-off to Hlalanathi. He was facing the opposite direction waiting for his lift to work when the sky lit up, and he turned round to see the object passing over Hlolela peak moving towards the direction of Montusi. The author visited the site and photographed the terrain in order to measure the altitude and azimuth of start and end points.

The meteor was bright with a yellow tail, and it looked like flames were coming off the tail. It gave a terminal burst and suddenly disappeared, after which he thought it would hit the peak at the summit of Oliviershoek Pass. The duration was roughly 3-5 seconds and about two minutes later he heard sounds like thunder which caused the ground to vibrate. Innocent Miya was riding his bicycle along the same road (D119) on his way to work. He gave a similar description to Wiseman.

- Several staff at the Cavern (51) witnessed the visible passage, and again the author was able to interview those who saw it. Sakhile Mlangeni saw it through a window facing azimuth ~280°. I measured the altitude as 28° moving left to right through a gap just below the tree line. The arc of travel was too small to discern its heading. Phelelani Mlangeni was finishing his shift on night watch, and had just turned the outside lights off under the thatched shelter between the tennis courts and bowling green at the hotel. As he was heading out he saw the bright light above the roof of the shelter, but immediately took cover in surprise. As a consequence he did not see the direction relative to the hotel buildings, but I ascertained the altitude as 45° in azimuth 240° at the moment he saw it.
- Several other Cavern staff members including Thokoza Mofokeng, Nomusa Mthetwa, Joseph Masabalala, Vuyisile Radebe, and Mbuyiseni Miya saw it from the main road in the Amazizi village, moving from the direction of Orion Mont Aux Sources hotel towards Hlalanathi. A minute or so later they experienced sounds and shaking like an explosion.

Further reports were analysed as the bolide moved through the Free State:

- Nduduzo Gumede (40) observed the meteor to the west from Newcastle. From his description of the path relative to landmarks seen from his location, I ascertained the end of the visible meteor in azimuth 280°, which together with those of locations 8 and 35 enable a tentative estimate for the point at which the meteor had ceased to emit visible light.

- Sandor Horvath (47) from Welkom had a good view of the passage moving northwards low in the east. From a sketch provided the azimuths of start and end point relative to local landmarks are roughly 144° to 90°. This places the end of the visible meteor a little further south of the points determined from Locations 8, 35 and 40.

The vast majority of reports were from Gauteng, where most probably thousands witnessed the demise of the bolide towards the northern end of its path. The most reliable reports were:

- Ruan Kuhn (45) saw the meteor from the intersection of Cowles Street and Main Reef Road, Springs while waiting for a change in the traffic lights. The object disappeared at low altitude to the south of his location, which led him to believe the object must have fallen nearby.
- Brendan Orsmond (8) had a ringside seat over Johannesburg from atop of his office block in Braamfontein, Gauteng, and was able to give a detailed description of the path which after measurement enabled determination of the northern limit of the visible meteor. The value arrived at is in good agreement with those from locations 35 and 40.

Finally, Frank Louw (49) was driving south on the R540 between Dullstroom and Belfast, and confirmed the visible meteor did not reach this far north, but must have burned out to the south. Most importantly, looking south he saw the object moving to his right, further constraining the angle of the path of the fireball.

Images from video recordings

In addition to the many visual reports, two sequences of video were obtained showing the passage of the visible meteor. Both sequences captured the latter parts of the path, including the bright flash, disintegration and burning out of the meteor, but neither captured the initial entry into the atmosphere.

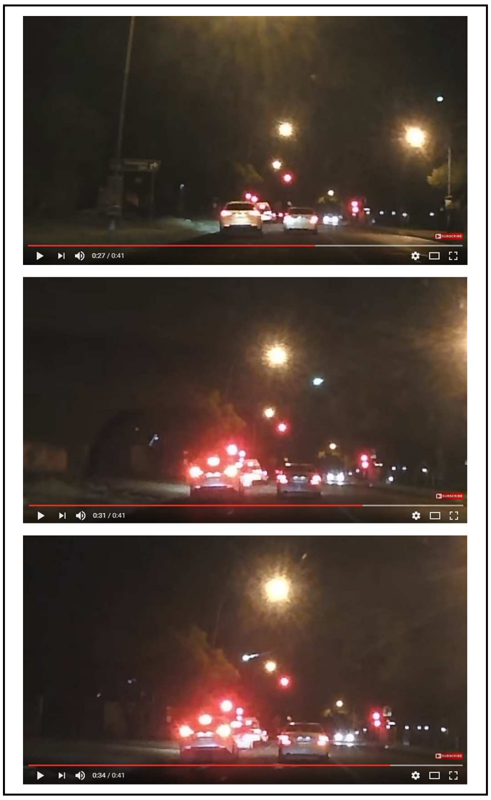

Fig 3. Screen grabs from dashcam footage at location 35

Location 35 was footage from a vehicle dashcam. Efforts to contact the witness were in vain, but knowing the area well I managed to isolate the exact location in Greenside, Johannesburg. The author visited the site and calibrated still images captured from the footage to give the start and end coordinates of the meteor. There is no time associated with the appearance of the meteor at upper right, but it descends to the lower left, and the duration of passage is around 8 seconds. Image captures are shown in Figure 3.

Fig 4. Screen grabs from security camera footage at location 50

Location 50 is from a security camera located in Chloorkop, Gauteng. It has the time imprinted, and the meteor enters upper right and descends towards lower left at a shallow angle. The time of appearance is 06h04m23s, the bright flash occurs at 06h04m27s, and the visible meteor ends at 06h04m29s. Image captures are shown as Figure 4

Reconstruction of the path from visual and video records and potential footprint for meteorite falls.

Determining the path of the bolide is important in projecting a forward trajectory and potential fall site of any meteorites assuming it survived its passage through the atmosphere. The probable path as derived from eye witness accounts is shown in Figure 2. The entry point into the atmosphere is indeterminate, as none of the accounts appear to have witnessed the start of the visible path with sufficient accuracy. The point of entry was certainly to the south of Dordrecht in the Eastern Cape, and a little to the east of that location according to the account from location 41. The accounts from locations 9, 30, 40, 47 and 51 are important to understanding the path of the meteor. Location 9 was sure the meteor passed overhead, while estimates of the altitude from locations 30 and 51 indicate the meteor had already descended to an altitude of about 30-40 km at about the point it passed over Fouriesburg. The accounts from locations 8, 40 and 47, and accurate measurements from the dashcam (35) enable a reasonable understanding of the termination of the visible meteor and the azimuths derived therefrom are shown in Figure 5. There is a good coincidence between locations 8, 35 and 40, which indicate the end of the visible path occurred in the northern Free State, near to the towns of Frankfort or Cornelia. While the point derived from location 47 is a little further south, it at least indicates the meteor must have passed the town of Reitz in the Free State.

The two sets of video footage indicate the meteor started to disintegrate at least several seconds before end of the visible passage, and these smaller fragments continue to ablate well after the disintegration. This fact is evident in the lower image of Figure 3 and the centre image of Figure 4. It should also be born in mind that the object entered earth's atmosphere at a shallow angle of about 20°, and so probably experienced severe heating due to passage through a large air mass. It is therefore likely that the object, with a pre-atmospheric size of 10-100 cm assuming a magnitude of -13 to -15, may have burned up entirely during its flight. If any fragments did survive, and based on the probable path and northern visible limit derived from the eye witness accounts, meteorites might be possible somewhere in the north-eastern Free State or south-western Mpumalanga.

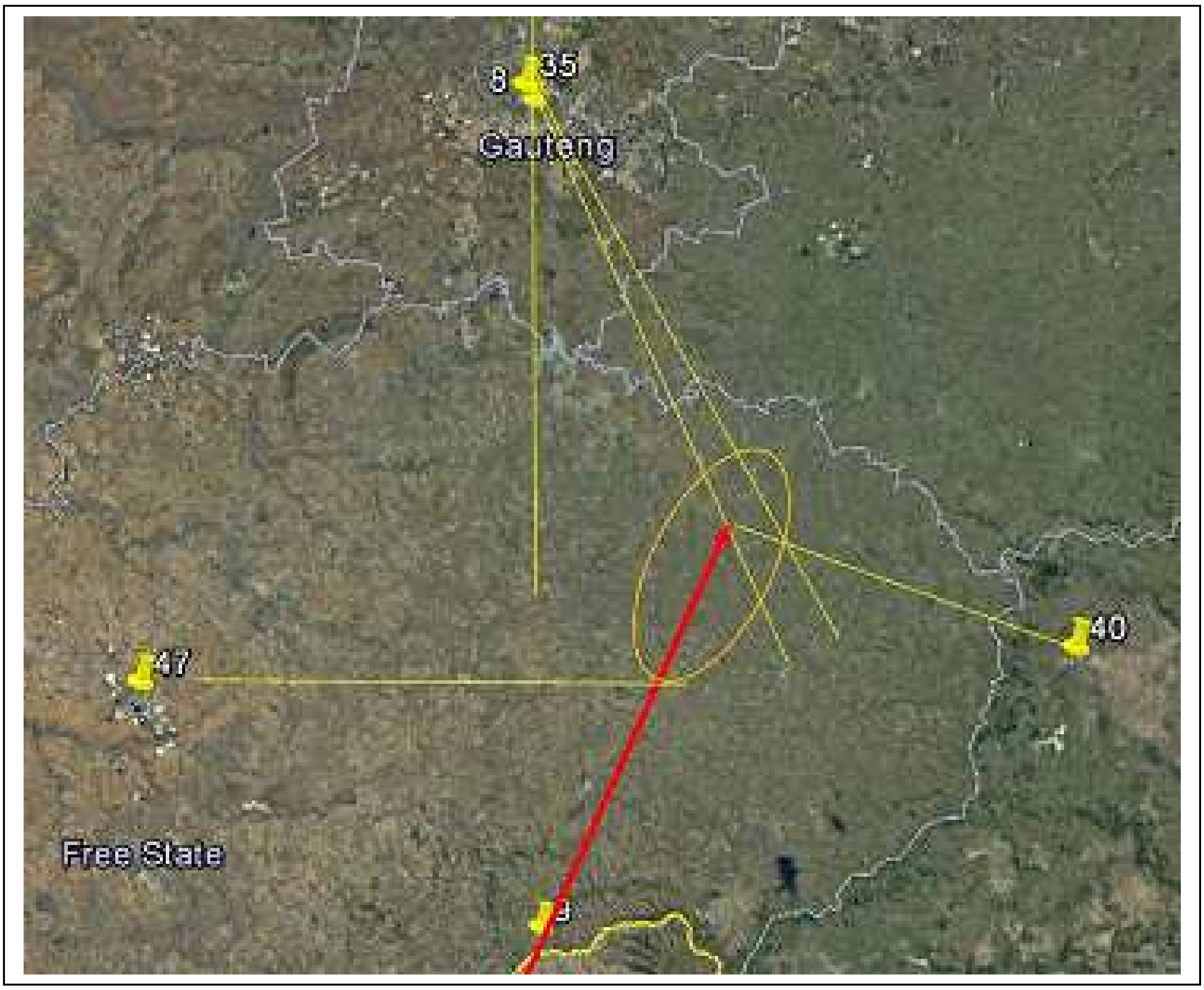

Fig 5. Probable end location of visible meteor over north-eastern Free State

Characteristics of the visible meteor

The time of passage was quoted variably from 05h55 to 06h05 SAST, the general consensus being just after 06h00. Ronald Nair was very certain about his time being 06h03, and the footage from the security camera has the time imprinted on it as 06h04. Again the estimates of the duration of the visible meteor vary considerably, from 2-3 seconds being the shortest, to 15 seconds being the longest. However, in terms of the shorter reported durations, it is probable the observers only saw a small part of the overall passage. The meteor was visible for 8 seconds in the dashcam footage, though it is not clear how long it was visible before it entered the frame.

Estimates of the brightness of such events are normally highly subjective, and very often over-estimated. One reason for this is the absence of suitable celestial objects at similar brightness for comparison. While most agreed the object was very bright, and some said it lit up the sky, there were only four direct references. One observer from near Durban quoted 'very bright, could be described as nearly as bright as the sun', while the remaining three, all in Gauteng said 'brighter than the full moon, similar intensity to full moon, and close to that of the full moon'. One report also commented 'It made a few flashes so the brightness was more intense at some points than others'. From this I conclude the brightness may have peaked somewhere between magnitude -13 to -15, though this cannot be confirmed for certain.

The observation of colour in meteors is similarly subjective, and depends on a number of factors. Firstly light is emitted due to excitation of metals which emit light on return to their ground state, the specific wavelengths depending on the metals involved. Typical colours emitted by meteors (Rendtel 1993) are blue-violet from calcium and magnesium, yellow-green from sodium and iron, and red from silicon. The brightest emission lines in meteor spectra are normally the H and K lines from calcium. Secondly, very energetic processes during entry of the body into the atmosphere cause excitation of atmospheric gas molecules, which then radiate light in the visible region, for example green from oxygen and red from nitrogen. Persistent green meteor trains have been shown to be due to the forbidden line of atomic oxygen at 557.7 nm (Evans 2003), and this emission is catalysed by the presence of sodium in the meteor (Beech 1987). The light emitted by the meteor may be subsequently affected by which process predominates, extinction effects due to altitude, and variable perception by the observer. Furthermore these factors may also vary along the length of the path, as the meteor loses kinetic energy and descends in altitude. In terms of the eye witness accounts green (35%) was most often mentioned in terms of the body of the meteor, followed by white (18%), blue (15%), yellow (15%), red and orange (17% combined). Fewer commented on the colour of the trail, with only nine cases, these being green (2), blue (2), yellow (2), orange (2) and red (1). I also looked at the colours seen from different locations along the path; so at the southern end Ronald Nair saw it as yellow/orange, while only slightly more north Warren Hale saw it as distinctly green. Around mid-passage at Fouriesburg, Letitia Veltman saw the colour of the meteor overhead as bright white. Moving further northwards Sandor Horvath in Welkom witnessed green. The greatest number of reports were from Gauteng, and here blue, white, but most often green were the predominant colours seen. Bearing in mind the aforementioned subjectivity, there does not appear to be any significant shift in overall colour perception along the path of the meteor.

Two observers may have witnessed nearly the whole passage of the bolide. Mark Sliep observed from Gauteng, saying ‘first saw it as a small glowing dot that grew into a big fireball with a tail, big enough to see debris falling from it and burning up as they fell. The main ball was slightly brighter than a full moon with a greenish tinge to it’. Frank Louw was driving due south near Dullstroom and reported ‘I saw what first looked like a bright white light not moving fast. I pointed to its direction showing my wife. We saw it first as a single light ball but as it reached the horizon it broke up into several pieces.

Audible sound reports

Sounds associated with the passage of bright meteors may be normal or anomalous (Vinkovic et al 2002) and include:

1. Rumbling, similar to that of distant thunder.
2. Single or recurring sharp cracking noises.
3. Fizzing or hissing sounds, known as electrophonic noise.

The first two (normal) occur sometime after the visible passage depending on the distance of the fireball from the observer at the time of the event, while electrophonic noise (anomalous) occurs simultaneously with the visual observation. Type 1 sounds due to acoustic waves may be detected audibly, and seismically if they are ground-coupled (Edwards et al 2008), in which case it feels like the ground is shaking. In regard to this event only Type 1 sounds were reported, mainly from locations in the eastern Free State and northern Drakensberg regions as follows:

- A loud bang was heard at Hlalanathi (14), where Mary Walker said it caused the windows to rattle.
- Standing waiting for his lift, Wiseman Kurauone (30) saw the meteor and about two minutes later heard sound ‘like thunder which caused the ground to vibrate’.
- At the Cavern (51) many staff heard sound like distant thunder, Megan Bedingham said it caused the windows to shake, and Jackie Ponsford thought it was actual thunder.
- Closer to the path at Phutaditjhaba (25), Mpho Mafika said the meteor was followed by a thunder-like sound. At the same location Modikadika Motaung reported ‘a thunderous sound that lasted for like 10 seconds, it was really loud’.
- At Fouriesburg, which was apparently right underneath the path, Letitia Veltman (39) ‘heard two deep 'boom' sounds, like massive explosions, but far away. These sounds were heard about 2 minutes after the visible flash’.

Conclusions

Based on the foregoing analysis, it appears a small fragment of asteroid entered earth's atmosphere at 06h04 SAST, at a shallow angle of around 20°. The duration of visible passage was >8 seconds, during which time the meteor probably reached about magnitude -13 to -15 in a bright flash near the end of its path, and disintegrated several seconds before finally burning out. The point of entry was most likely to the south of Dordrecht in the Eastern Cape, passed overhead near Fouriesburg and the visible path ended somewhere near the towns of Frankfort or Cornelia in the north-eastern Free State. If any fragments persisted, they might have deposited as meteorites in the area of the north-eastern Free State or south-western Mpumalanga.

Acknowledgements

The author wishes to thank those who forwarded reports of the object, particularly Kos Coronaios (ASSA Observing Director), Willie Koorts (Sterre en Planete FB page), Samson Chiyaka who coordinated reports from the Cavern and vicinities, Stewart Wasserfall who assisted at the site of the dashcam footage and for providing a most delightful Biryani, and Dr Tana Joseph (SAAO Outreach astronomer). My thanks also to Robert Lunsford for forwarding details of five reports sent directly to the IMO website. Figures 1, 2 and 5 courtesy of Google Earth Pro Ver. 7.1.5.1557.

References

Beech M., 1987, On the Trail of Meteor Trains, *QJRAS*, **28**, 445-455.

Chamberlin A.B., 2017, JPL/Caltech site cneos.jpl.nasa.gov/fireballs/.

Cooper T.P., 2011, Fireball and Bolide Observations: 2009-2010, Event #225, *MNASSA* **70**, Nos.5&6, 109-110.

Cooper T.P., 2013, The Daytime Bolide of 12 March 2013, *MNASSA* **72**, Nos.3&4, 47-52.

Cooper T.P., 2017, Definitions of terms in meteor astronomy and recent Southern African Fireball Observations, *MNASSA* **76**, Nos.5&6, 121-128.

Edwards W.N., Eaton D.W. and Brown P.G., 2008, Seismic observations of meteors: coupling theory and observations, *Reviews of Geophysics* RG, **46**, paper number 2007RG000253.
Evans S.J., 2003, The colours of photographed Leonid meteors, *JBAA*, **113**, 326-328.
Rendtel J., 1993, Table 3-7: List of spectral lines frequently found in meteor spectra and their relative intensities, in IMO Photographic Handbook, Part 3: Meteor Spectra.
Vinkovic D., Garaj S, Lim P.L., Kovacic D., Zgrablic G and Andreic Z, 2002, Global Electrophonic Fireball Survey, WGN, 30:6, 244.

Imaging the close approaches of some Near Earth Asteroids

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Introduction

Most asteroids orbit the Sun harmlessly between the orbits of Mars and Jupiter, and with semi-major axes (a) between 2.2 and 3.3 AU are referred to as main belt asteroids. There are however families of asteroids who, due to the fact they have perihelia (q) ≤ 1.3 and aphelia (Q) ≥ 0.983, can make a close approach to Earth in their orbits, and as a result are referred to as near Earth asteroids (NEAs). The NEAs may be classified into three families (Bottke et al 2002):

- Apollos, with a ≥ 1.0 and q ≤ 1.017 AU, having orbits larger than the Earth's but their perihelion distances are inside the Earth's orbit at their aphelia. These asteroids are Earth crossers with the capability of impacting the Earth and may also be referred to as potentially hazardous asteroids (PHAs). Known examples are 1866 Sisyphus, 69230 Hermes, 4179 Toutatis, 25143 Itokawa, and 3200 Phaethon.

- Atens have a < 1.0 AU and Q ≥ 0.983 AU, having orbits smaller than Earths but their aphelion distances are outside Earth's orbit. They are also Earth crossers and therefore capable of impacting the Earth. There are currently around twenty known members of the Aten family including the now well-known example 99942 Apophis.
- Amors having perihelion distance 1.017 < q ≤ 1.3 AU. This means that even when the asteroid is at perihelion and the Earth is at aphelion, the orbits do not intersect, but the asteroid can make a close approach to Earth's orbit. The most well-known example is 433 Eros.

While we have no reason to believe that Earth is in any more danger of a collision than before, there has recently been much excitement surrounding the particularly close approaches of several NEAs. So with the comforting knowledge that we were not in any potential danger, the authors opened up their telescopes and imaged the recent close approaches of asteroids 357439 (2004 BL86), 2014 JO25 and 3122 Florence.

Asteroid	Date/time of close approach UT	Miss distance LD	Brightest magnitude	Type
2004 BL86	2015 26 Jan , 16h19	3.1	9.2	Apollo
2014 JO25	2017 19 Apr, 12h24	4.6	10.7	Apollo
3122 Florence	2017 01 Sep, 12h06	18.4	8.7	Amor

Table 1. Close approach details. Miss distance is given in mean distance of the Moon from Earth (LD).

Asteroid 2004 BL86

The close approach on 25 January, 2015 was the closest this NEA will come to Earth in the next two centuries, so we did not want to wait for the next one! Moreover, the miss distance of only 3 LD is the closest approach of an asteroid of comparable size until that of the 800 metre-wide 1999 AN10 in 2027 at a distance of only 1 LD (Agle 2017). Despite poor weather this asteroid was imaged by Tim Cooper and Kos Coronaios. The time of closest approach was just before dusk, and both had a frustrating wait for gaps in the cloud as evidenced by Fig. 1, but were eventually able to secure several images later in the evening, including the passage near to the open cluster M48 in Hydra. Fortunately the clouds did clear sufficiently for Kos to obtain a nice trail as it passed nearby the cluster shortly around 18h00 UT (Fig. 2). Tim Cooper was left wondering if he would get to image anything apart from the underside of a thick cloud deck, until his persistence was rewarded around midnight with a clearing in which he managed about an hour of imaging. He secured 200 x 10 second images which were processed and stacked, a selection of which are shown in Figs. 3 and 4.

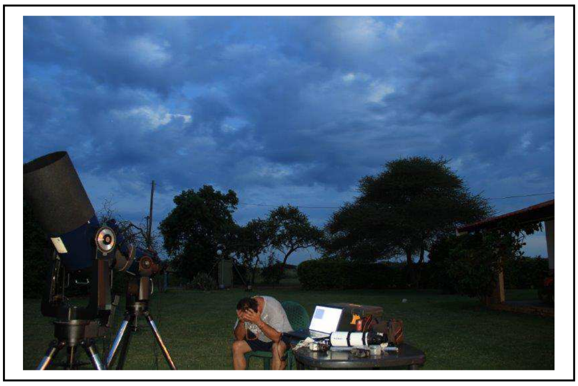

Fig 1. An amateur astronomer's nightmare, a one-time observing opportunity and Kos Coronaios praying for the clouds to clear?

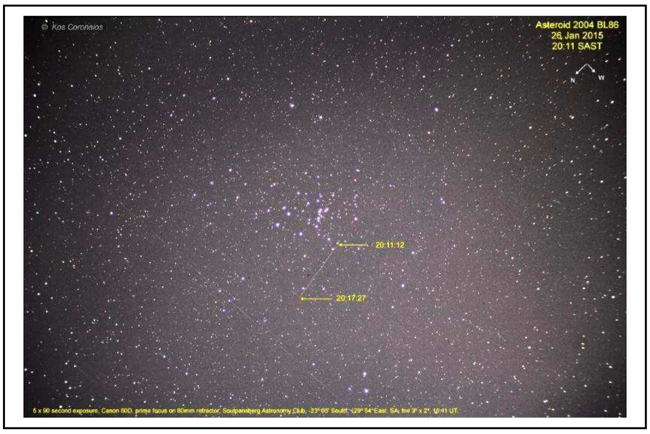

Fig 2. ***Asteroid 2004 BL86*** *passing Messier 48. Image by Kos Coronaios, Canon 60D at prime focus of 80mm f/5 refractor, stack of 5x90 second images starting at 18:11:12 UT. Movement of the asteroid is from upper right towards bottom left, ie towards north.*

The skies closed up again around 1 am local time which ended the observing run for the night.

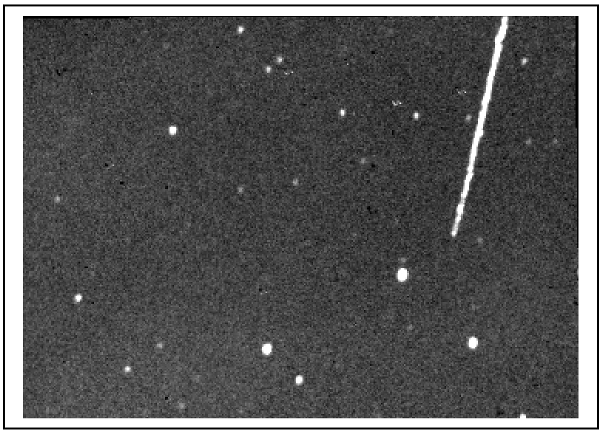

Fig 3. ***Asteroid 2004 BL86****. Image by Tim Cooper, 30cm Meade LX90 SCT. Starlight Xpress SXV-M7 camera, 2x2 binning, unfiltered, 10x10 second exposures started at 21:49:25 UT, registered and average combined. Frame size 11.0' x 8.5'. COF RA/Dec = 08h23m40s +03°30'. Movement of object is towards top right (northwards), east is towards the right. Δ = 0.0082 AU, mv=9.4. Brightest star just to lower left of the start of the track is PPM 154398, magnitude 10.7. The faintest stars in the image are around magnitude 15.*

Fig 4. ***Asteroid 2004 BL86****. Image by Tim Cooper, details as above, 10x10 second exposures started at 22:06:02 UT. COF RA/Dec = 08 24 28 +04 11. Δ = 0.0083 AU, mv=9.4. The centre star of the three just above the track is TYC 0205-01511-1, m_V= 10.7. The faintest stars in the image are around magnitude 16. There are several faint galaxies visible in the image, the brightest at the top centre being PGC23590 = 2MASX J08242584+0414517 = MCG +01-22-010*

Asteroid 2014 JO25

Imaging this asteroid was probably the most difficult of the three; not only as it was the faintest at magnitude 10.7, but more so because of low altitude in the north and speed as it crossed the sky at more than 2°/hour. To observe this asteroid required careful planning beforehand. In the event the asteroid was too low for Tim Cooper and was obscured by his observatory roof, which runs off to the north. Years ago when he built the observatory it was built with unobstructed views to the east and west, purposely sacrificing the view to the north, and faced with the prospect of lugging the whole setup outside for this event he decided to forego the opportunity. Fortunately the second and third authors were more fortunate (or maybe they just planned better!). Oleg Toumilovich tracked the fast-moving asteroid for three hours, capturing hundreds of images, an example of which is shown as Fig. 5. Kos Coronaios also managed to image the asteroid under difficult conditions, as shown in Fig. 6.

Fig 5. ***Asteroid 2014 JO25****, Image by Oleg Toumilovich, 2017 April 19, 22h10 UT, single 30 second exposure at ISO800 using a Canon EOS-550D camera, 20cm Celestron f/6.3 telescope.*

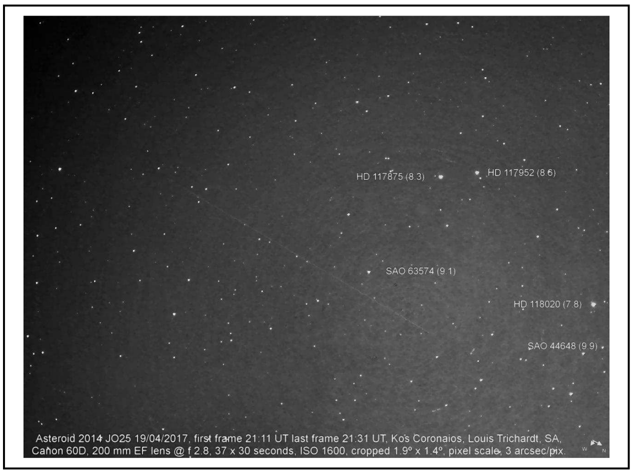

Fig 6. ***Asteroid 2014 JO25****, Image by Kos Coronaios, 2017 April 19, Canon 60D with 200mm lens set at f/2.8, 37 x 30 second exposures at ISO1600 first image at 21:11 and last image at 21:31 UT. Frame is 1.9° x 1.4°. Movement of the asteroid was from bottom right towards top left, and it travelled 58' across the sky during the period of exposure.*

Asteroid 3122 Florence

The close approach of 3122 Florence was the most favourable for observation, being a much larger and consequently brighter object, and well situated high in the sky as darkness fell. However, the miss distance was 5-6 times that of the 2004 BL86 and 2014 JO25, meaning that it was much slower moving. For several days centred on 1 September, 2017 asteroid 3122 Florence was brighter than ninth magnitude, allowing us plenty of time to prepare as a result. Closest approach at 12h06 UT on September 1 occurred during daylight hours for southern Africa, but all three authors managed to image the asteroid for a short period immediately after dark. Tim Cooper secured 540 x 10 second images between 17h00 and 18h00 UT, which were stacked and aligned to form a mosaic of the path during exactly one hour (see Figs. 7 and 8). While the evening started out perfectly calm, an hour into the session a cool breeze came up, which by 9.30 pm local time had escalated into a gale force wind, ending any further imaging opportunities. Kos Coronaios imaged the asteroid with a DSLR camera on three nights, including 30 August – 1 September.

Fig 7. ***Asteroid 3122 Florence****. Images by Tim Cooper, 2017 August 31, showing movement of the asteroid over an interval of 5 minutes, single 5 second exposures, start of top exposure at 16:56:07 UT, start of bottom exposure at 17:01:15 UT. 30cm Meade LX90 SCT telescope, Starlight Xpress SXV-M7 camera. Each frame is 11.9' x 8.5'.*

Figs. 9 and 10 show the path on the first and last dates, passing through a rather barren section of sky devoid of deep sky objects. Finally Oleg Toumilovich secured hundreds of images from which he was able to produce an animated video of the asteroid crossing the sky. Before closing up for the evening all three observers were able to observe the asteroid at the eyepiece, and as it slowly moved across the field of view, reflect on the damage this large chunk of rock might have done under different circumstances.

Fig 8. ***Asteroid 3122 Florence****. Image by Tim Cooper, 2017 September 1, montage of 540 x 5 second exposures, gaps in path during repositioning of telescope to follow fast-moving asteroid. 30cm Meade LX90 SCT telescope, Starlight Xpress SXV-M7 camera. Time of first image = 16h58m34s UT. Time of last image = 17h58m16s UT. Movement of object is towards upper left. Brightest star at left of the bottom right frame is PPM171010, magnitude 9.3. Faintest stars are ca. magnitude 18.*

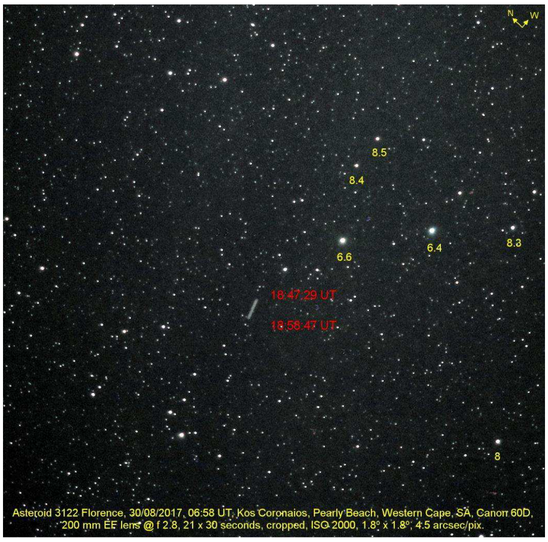

Fig 9. ***Asteroid 3122 Florence****. Image by Kos Coronaios, 2017 August 30, Canon 60D with 200mm lens set at f/2.8, 21 x 30 second exposures at ISO2000 starting at 18:47:29 UT. Movement of the asteroid is from upper right towards bottom left. Frame is 1.8° x 1.8°.*

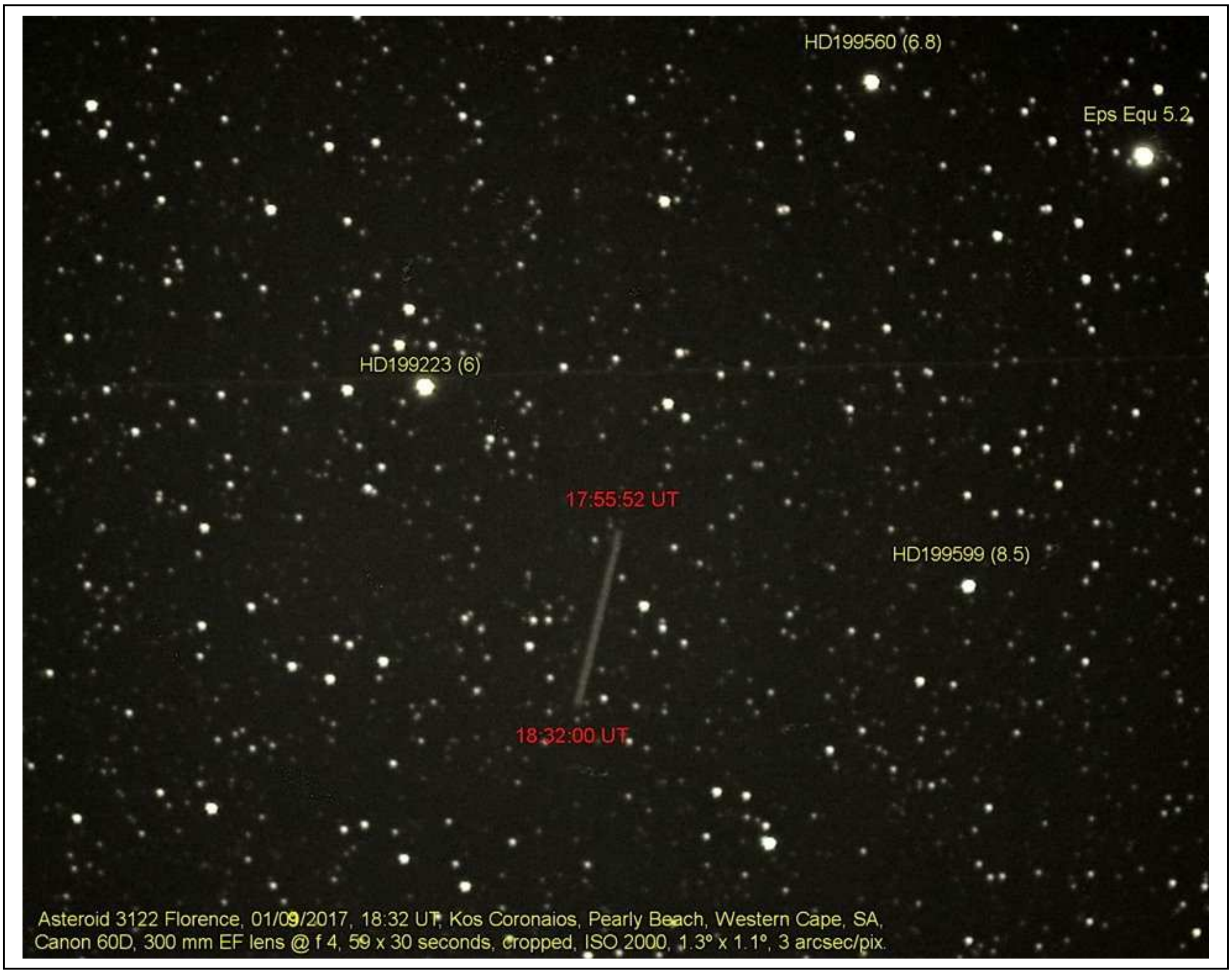

Fig 10. ***Asteroid 3122 Florence****. Image by Kos Coronaios, 2017 September 1, Canon 60D with 300mm lens set at f/4, 59 x 30 second exposures at ISO2000 starting at 17:55:52 UT. Movement of the asteroid is from upper right towards bottom left, ie towards north. Frame is 1.3° x 1.1°.*

Postscript

Subsequent to their close approaches, all three asteroids were found to be rather complex bodies. Asteroid 2004 BL86 has a diameter of 325 metres, and is accompanied by a small moon with a diameter of 70 metres, Asteroid 2014 JO25 is a peanut-shaped contact-binary asteroid, and Asteroid 3122 Florence moves through the solar system with two small moons.

Fig 11. ***Asteroid 3122 Florence****, Image by Oleg Toumilovich, 1 September, 2017, stack of 30 images showing motion from 19h12-19h16 UT, Canon EOS-550D camera set at ISO800, 20cm Celestron f/10 telescope. South is towards the top and east to the right, and the frame is 32.5' x 22.6'. The width of the field is similar to that of a low power eyepiece, and the image gives a good idea of the motion of the asteroid as seen by the observer over a 4 minute period. The star just to the left ofthe track is magnitude 11.7 GSC 521630. The brightest star just inside the right edge is the eclipsing binary S Equ, which varies between magnitude 8.0 and 10.0 in a period of just under 3.5 days.*

Acknowledgements

The first author thanks Auke Slotegraaf for identifying all the faint fuzzy objects in Image 4.

References

Agle D.C., 2017, https://www.nasa.gov/feature/jpl/asteroid-to-fly-safely-past-earth-on-april-19

Bottke W.F., Cellino A., Paolicchi P., and Binzel R.P., 2002, An Overview of the Asteroids, in Asteroids III, University of Arizona Press.

The meteor stream associated with Comet C/2015 D4 (Borisov)

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Summary
Following the prediction by Jenniskens and Lyytinen (2017) of potential meteor activity from comet C/2015 D4 Borisov the authors conducted visual observations and low-light CCTV imaging to determine whether any meteor activity occurred due to intersection of the earth's orbit with that of the dust trail. The setup process and results obtained are summarised in this paper. Analysis shows that 167 meteors were captured simultaneously from the two stations at Bredell and Victory Park, but activity from the trail of comet Borisov could not be confirmed. Most of the video detections were Southern delta Aquariids, but in addition diffuse activity was detected from a radiant around R.A. = 20°, Dec. = -15°, and also from a compact radiant around R.A. = 40°, Dec. = -32°. Observations by Cooper suggest possible weak visual activity may have occurred between 02h00-03h00 UT, a little later than the predicted time.

Background
Comet C/2015 D4 (Borisov) was discovered by G. Borisov on CCD images taken with a GenonMax 0.3-m f/1.5 astrographic telescope (CBET 4071). Due to the faintness of the object, a lack of good astrometric data did not permit an accurate determination of the orbit at that stage. Borisov had in fact discovered his comet some four months after it passed perihelion on 2014 October 28, at a distance of 0.86 AU. The comet at the time of discovery was total visual magnitude (m1) = 16.8 (Yoshida 2017) and by

end June had faded to m1 = 20. Extrapolating the brightness at perihelion using the general equation for total cometary magnitude:

$$m1 = m0 + 5\log\Delta + 2.5n.\log(r) \qquad (1)$$

where the absolute magnitude m0 was taken as 6.5, and Δ and r are the geocentric and heliocentric distances of the comet respectively, the comet likely peaked at magnitude 12, but the circumstances were not favourable for discovery at that stage. After perihelion, the comet remained close to the horizon as it passed through Scorpius and Sagittarius, which would explain the late discovery some months after perihelion passage. In all likelihood the comet was small, intrinsically faint and not very active after perihelion.

The potential for meteor activity from comet C/2015 D4 Borisov was first mentioned by Jenniskens et al (2015), and that the comet might be responsible for meteors due to intersection of the 1-revolution dust trail with earth's orbit at its ascending node. Activity was predicted with a duration of about one hour from a radiant at R.A. = 79°, Dec. = -32° with a geocentric velocity of 45.9 km/s in both 2017 and again in 2029. Subsequently the acquisition of more accurate astrometric data enabled Jenniskens and Lyytinen (2017) to announce that the earth would pass through the 1-revolution dust stream at a distance of only $r-\Delta = +0.0006$ AU on 2017 July 29 at 00h22 UT (solar longitude 125.858°). The predicted radiant position and geocentric velocity remained unchanged. It should be noted that a previous encounter with the stream occurred on 2006 July 29 at 04h11 UT, at which time no activity was observed, though the possibility of meteors was then not expected as the comet was yet to be discovered. Future favourable encounters will occur again in 2029 (very favourable for Southern Africa), and then in 2042 and 2053 (both unfavourable for southern Africa). Given the circumstances in 2017, the authors conducted both visual observations and low light CCTV imaging with the view to confirming any activity from the potential meteor shower.

Fig 1. Low light video camera array used at Bredell. The cameras are Watec 904H cameras, set at f/1.2, and with sensitivity of 0.0001 lux.

CAMS@SA Network setup

The authors set up a double station array each with four low light cameras (sensitivity 0.0001 lux) at Bredell and Victory Park as part of NASA's Cameras for All-sky Meteor Surveillance (CAMS) project in collaboration with the SETI Institute. The intention is to convert this to a permanent network with additional cameras being added to increase sky coverage, using the comet Borisov event to gain experience with the cameras, software and data capture process. Once fully operational this network will be referred to as CAMS@SA. The cameras were oriented so as to overlap the fields of view to capture meteors at an altitude of 90 km above the earth's surface. The camera array is shown in Figure 1 and the overlap achieved from the two sites at Bredell and Victory Park can be seen in Figure 2 (diagram courtesy of Jim Albers). After alignment the cameras were calibrated remotely to enable determination of the trajectories of any meteors captured. Both sites were operated with remote assistance from Steve Rau and Peter Jenniskens, with additional analysis post event by Peter Gural. From the coordinates of meteors captured simultaneously it is possible to triangulate and solve for the orbital elements of each observed meteor, from which data a shower map can be generated to identify potential radiants of observed meteors. As example, Figure 3 shows one such meteor captured at both sites, and identified from its orbital elements as a Southern delta Aquariid.

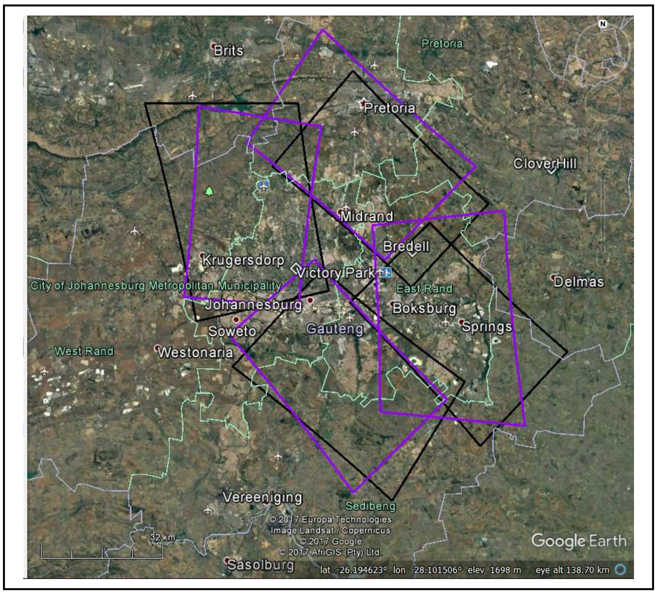


Fig 2. Overlap of fields of view of cameras at Bredell and Victory Park. Map courtesy Jim Albers.

Figure 3. Double station Southern delta Aquariid (SDA) observed on both camera 579 at Victory Park and camera 587 at Bredell.

Results for CAMS@SA First Light run

Prior to observing the comet Borisov event we conducted CAMS@SA first light trial runs during the night of 2017 July 22/23. Due to the excellent preparation by all concerned, the trial runs worked flawlessly, and resulted in orbital elements for 87 meteors observed simultaneously that night. A selection of meteor images captured from the Bredell cameras is shown in Figure 4. These meteors were also captured by the Victory Park cameras enabling determination, clockwise from upper left, as CAP, SDA, CAP, Sporadic, SDA and SDA. The resultant shower map is shown in Figure 5, and shows clear activity of the Southern delta Aquariids (IAU shower code SDA) and alpha Capricornids (CAP).

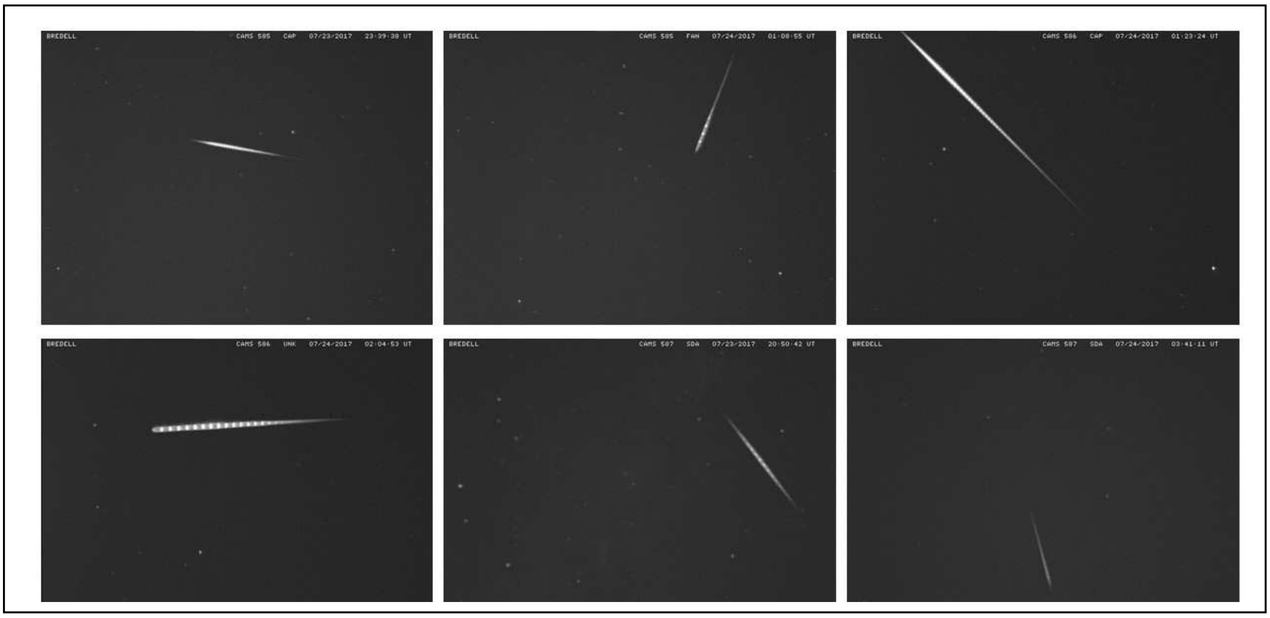


Figure 4. Selection of meteor images captured on Bredell cameras during the First Light trial run.

CAMS results for comet Borisov trail

Following the successful trial run, both CAMS stations ran throughout the night of 2017 July 28/29, starting the capture process immediately after darkness fell, and continuing until 04h00 UT just before dawn light became strong enough to saturate the cameras. The full nights run resulted in 167 meteors captured simultaneously from the two stations at Bredell and Victory Park. However, analysis shows the majority of these could be traced back to the radiant of the Southern delta Aquariids, an annual shower which reaches its maximum about the same night. The shower map generated from meteors captured during the night of July 28/29 is shown in Figure 6. No meteors were detected coincident with the trail of comet Borisov. In addition to activity from the SDAs, diffuse activity was detected from a radiant around R.A. = 20° (01h20), Dec. = -15°, located in the constellation of Cetus, and also from a compact radiant around R.A. = 40° (02h40), Dec. = -32°, located near the star β Fornacis. Neither locations coincide with any previously known meteor activity at this time of year (Jenniskens 2006), and their existence remains to be confirmed. The network also showed its usefulness to detect and confirm bright meteors, or fireballs, as shown by the example in Figure 7, captured in the early evening of July 29.

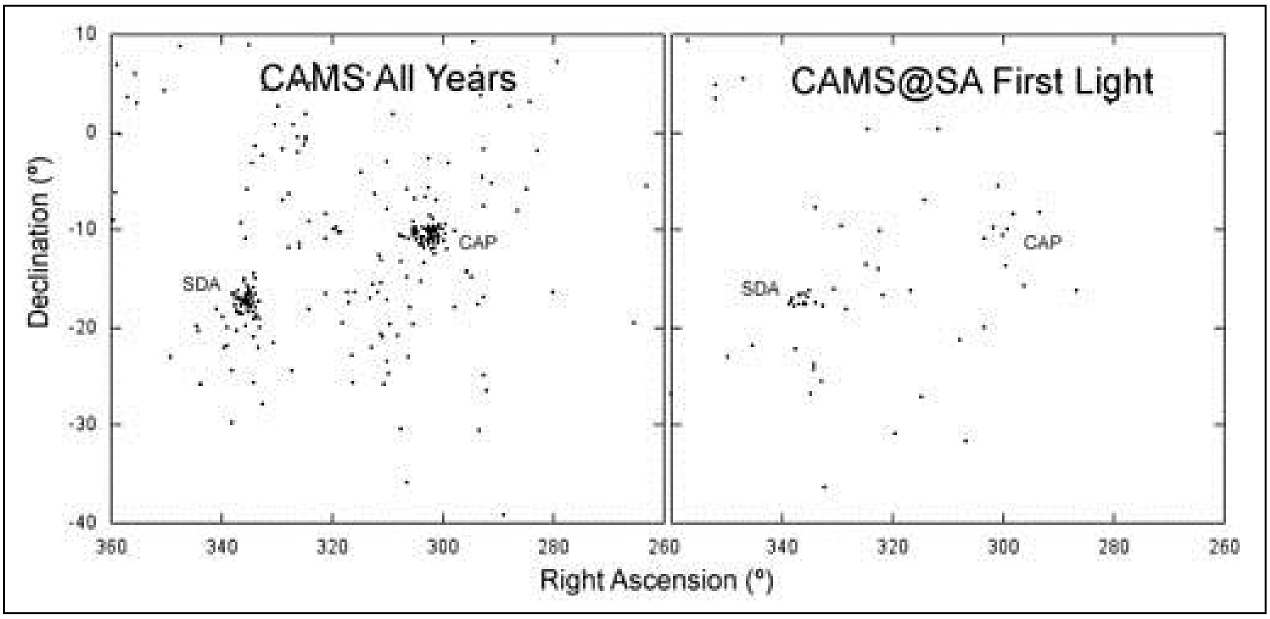


Fig 5. Shower map showing meteor orbits for night of 2017 July 23/24 (right) in comparison to global CAMS data for all years (left). Activity from the Southern delta Aquariids (SDA) and alpha Capricornids (CAP) is clearly seen.

Visual observations of comet Borisov meteors and other possible activity

Cooper conducted visual observations totalling 3.37 hours. During this time he observed 30 meteors under conditions of limiting magnitude 5.2-5.4. The overall results are given in Table 1.

Date 2017	Time UT	Field α,δ	T_{eff} hours	LM	COL	SDA	PSA	ERI	CAP	SPO	Total
Jul 28/29	2343-0051	030, -21	1.05	5.2	0	5	2	0	1	1	9
Jul 28/29	0057-0158	045, -40	0.92	5.3	0	6	1	0	0	4	11
Jul 28/29	0204-0256	090, -42	0.80	5.4	3?	0	0	0	0	2	5
Jul 28/29	0307-0344	090, -42	0.60	5.4	0	0	2	0	1	2	5
Total			**3.37**		**3**	**11**	**5**	**0**	**2**	**9**	**30**

Table 1. Times of visual observation and meteors observed by Cooper

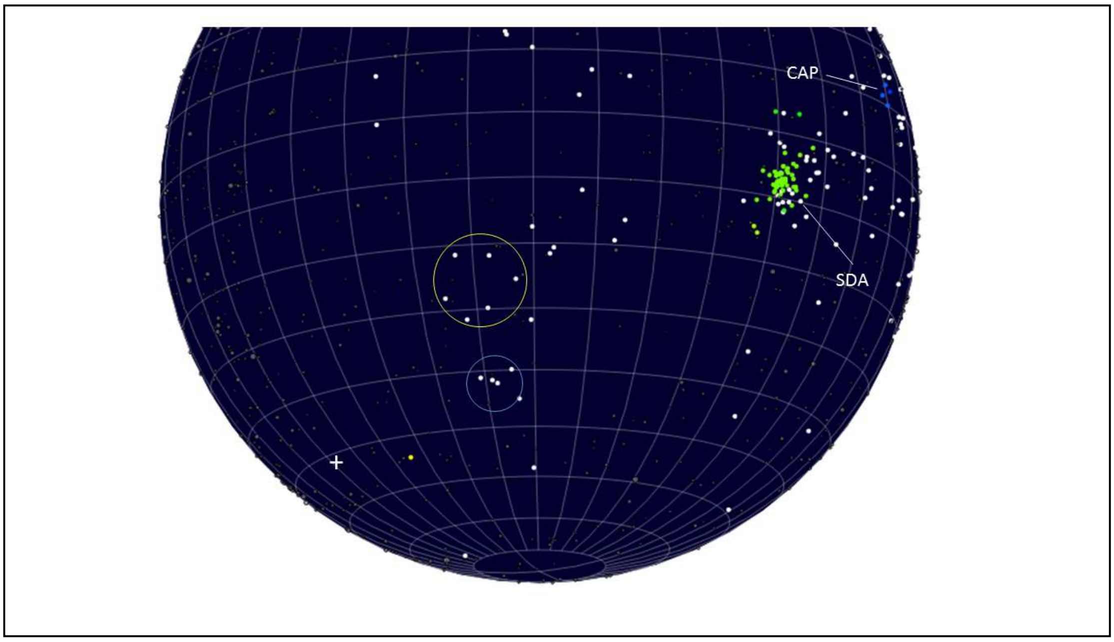


Fig 6. Shower map showing meteor orbits for night of 2017 July 28/29. Southern delta Aquariids (SDA) are shown as green dots, alpha Capricornids (CAP) as blue dots, all other meteors as white dots. Stars are grey dots. Position of the comet Borisov radiant is shown as a white +, the vicinity of the Cetus radiant as yellow circle and that near β Fornacis as blue circle.

Fig 7. Possible fireball captured by two cameras at Victory Park. The two images have been aligned and joined to show the full path of the meteor. The constellation of Sagittarius is clearly visible to the right of the meteor.

The shower associations are COL=predicted meteors from comet Borisov, radiating from near the star omicron Columbae, SDA=Southern delta Aquariids, PSA=Piscis Austrinids, ERI=eta Eridanids, CAP=alpha Capricornids and SPO=sporadic meteors, not traceable to known radiants.

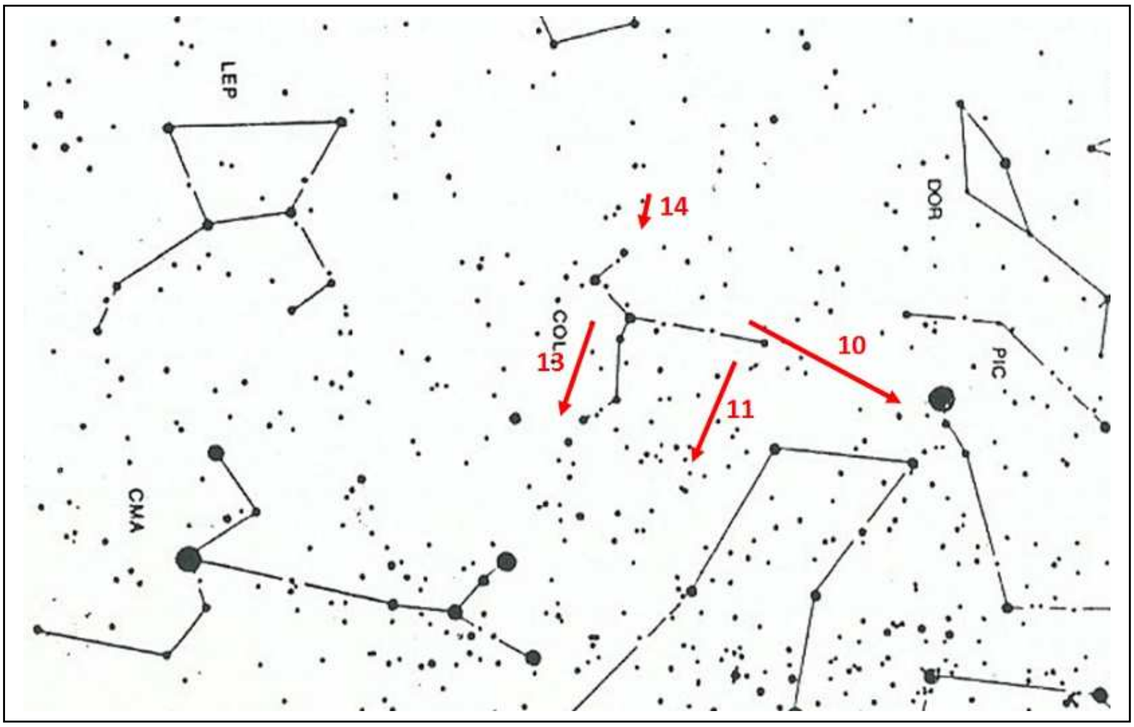


Fig 8. Meteors plotted by Cooper showing meteors observed in the vicinity of the radiant. Plots 13 and 14 show a high probability of coincidence with the predicted radiant of the comet Borisov stream.

The preponderance of meteors from the three main showers (SDA, CAP, PSA) known to be active and all reaching their maxima around the end of July is clearly evident in the visual data. Possible activity from the comet Borisov radiant in Columba (COL) was present only between 02h04-02h56 UT, with two meteors showing a high probability of coincidence with the predicted radiant position, seen at 02h43 and 02h51 UT, and shown as plots 13 and 14 in Figure 8. A third possible candidate was observed at 02h08 and shown as plot 10. However this meteor was only seen fleetingly and so the accuracy of the plot was noted as second class. All three possible Columbids were magnitude 3 and of medium speed. Nine meteors were noted as sporadic. Of these, two showed excellent coincidence with the radiant in Cetus at R.A. = 20°, Dec. = -15°, and were observed at 01h24 and 03h37 UT. Both were white and very fast.

Conclusions

No meteors were detected by video from the predicted intersection with the 1-revolution dust trail of comet C/2015 D4 Borisov. Two meteors were observed visually at 02h43 and 02h51 UT, with a high probability of coincidence with the predicted radiant. Video observations indicate the presence of two further weak radiants, at around R.A. = 20°, Dec. = -15°, in the constellation of Cetus, and around R.A. = 40°, Dec. = -32°, near the star β Fornacis. The radiant in Cetus was confirmed visually with two Cetids observed at 01h24 and 03h37 UT. Both were very fast, white meteors.

Acknowledgements

The authors wish to thank Dr Peter Jenniskens for his guidance, Steve Rau for his unstinting assistance in setting up and maintaining the software for the cameras, Jim Albers for assistance in setting up and pointing the cameras and Peter Gural for data analysis. The first author is greatly indebted to Judy Partridge for assistance with importation of the cameras in time to set up for the event.

References

CBET 4071, announced on 2015 March 3. Central Bureau Electronic Telegrams, No. 4071, (2015).

Jenniskens, P. (2006), in Meteor Showers and their Parent Comets, Table 7, Working list of cometary meteor showers, Cambridge University Press.

Jenniskens, P. Lyytinen E. and Bremer C., Potential meteor shower from comet C/2015 D4 (Borisov), Central Bureau Electronic Telegrams, No. 4127, 1 (2015). Edited by Green, D. W. E.

Jenniskens P. and Lyytinen E., Potential New Meteor Shower from Comet C/2015 D4 (Borisov), Central Bureau Electronic Telegrams, No. 4403, 2 (2017). Edited by Green, D. W. E.

Yoshida, S. 2017, light curve of comet C/2015 D4 Borisov from his website, www.aerith.net/

Analysis of recent eta Aquariid meteor activity

Tim Cooper, Bredell Obseratory

The eta Aquariid meteor stream, visible each year in early May, is the intersection of Earth's orbit with the outbound debris stream from comet 1P Halley. The intersection of Earth's orbit with the stream pre-perihelion results in the Orionids, visible in October. With the return of the parent comet to perihelion in 1986, observations of the meteor streams associated with the comet were requested as part of the International Halley Watch, IHW, (Edberg 1983) with the aim of providing data that would help better understand the comet. While the Orionids are equally visible from both hemispheres and so receive good observational coverage, the eta Aquariids can only be observed in a narrow window before dawn in early May, and favour observation from the southern hemisphere. The author has observed the eta Aquariids since 1988, initially as part of the IHW project, and has observed every year since without missing a single apparition.

Cooper (1996) provided a summary of activity of the eta Aquariids during the period 1986 to 1996. He concluded the shower peaked with zenithal hourly rate (ZHR) = 60-70 around solar longitude ($\lambda_{\odot}$) 43.5-44.0. There was evidence for a second maximum in some years around $\lambda_{\odot}$ = 46-47, and other authors (Wood 1995) have made reference to this later maximum. More importantly Cooper noted a tendency to show enhanced activity with ZHR>100 on occasions, the apparition in 1993 being a case in point, when the Earth probably passed briefly through a rich filament on the morning of 3 May as seen from South Africa. The most recent comprehensive summary of activity from both the eta Aquariids and Orionids was provided by Dubietis (2003). He commented on the long term activity from both meteor showers associated with 1P Halley, and concluded both may show periodic changes in activity, correlated with a period of very approximately 12 years. Furthermore, he noted the filamentary structure of the streams as evidenced by radio observations (Hajdukova et al 1987) and visually by Cooper (1996).

The eta Aquariids showed enhanced activity again in 2013 with ZHR=135±16 (Cooper 2013), and this paper summarises recent activity in the shower. The eta Aquariids are best observed from the southern hemisphere, and desperately need further observers from Southern Africa to help characterise the nature of the activity more accurately.

Zenithal hourly rates at maximum

Observed zenithal hourly rates (ZHR) at maximum over three decades are shown in Figure 1. Rates for 1986 to 2000 are based on Cooper (1996) and Dubietis (2003). Rates for 2000 to 2017 are based on data from the IMO Visual Meteor Database (VMD) and supplemented by recent observations by this author. Rates derived from the VMD need to be treated with some caution however, in that they are based on total global observations, very often from the northern hemisphere, where the radiant does not attain an appreciable altitude, and which may in some cases lead to high correction factors in the computation of ZHRs.

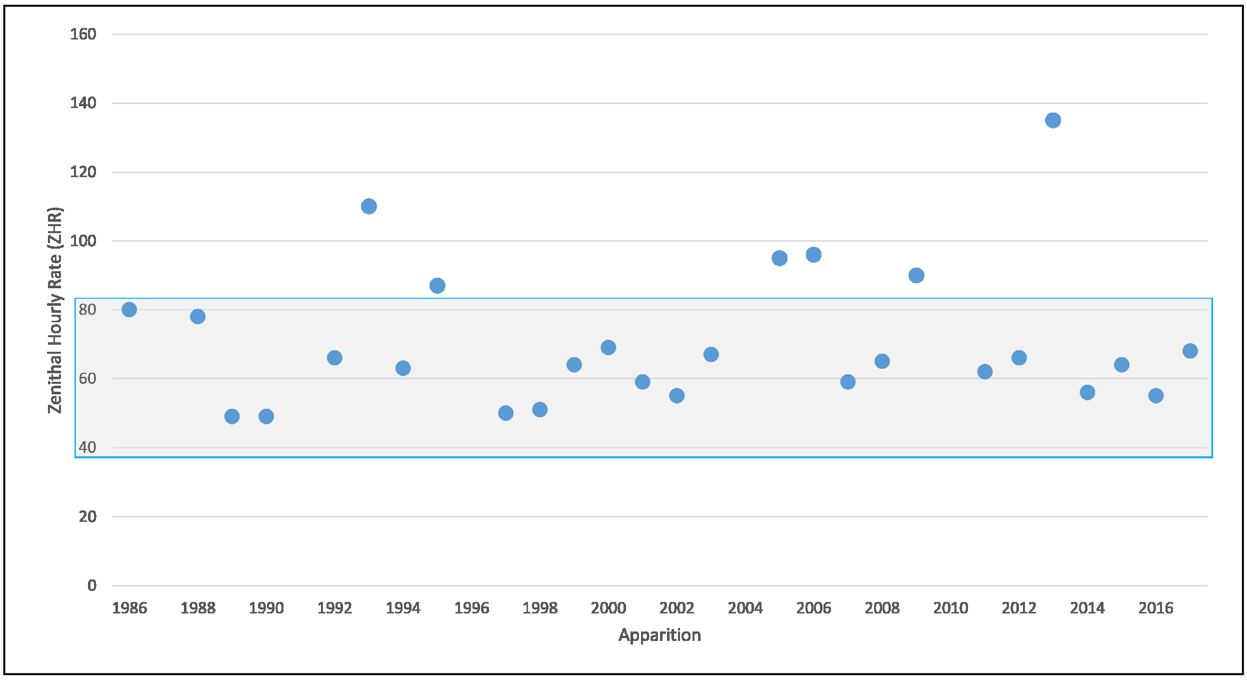


Fig 1. Long-term variation in ZHR of the eta Aquariids.

To normalise rates for all observers, the standard formula (1) is used to compute the ZHR, which is the number of meteors that would be expected under unobstructed skies, with limiting visual magnitude of 6.5 and with the radiant at the zenith. For the eta Aquariids however, the radiant only rises a couple of hours before sunrise, even in the southern hemisphere, and never attains more than about 50° altitude at best. The ZHR is computed according to:

$$ZHR = \frac{N.F.r^{(6.5-LM)}}{T_{eff}\,.\sin h} \qquad (1)$$

N	=	number of shower meteors
F	=	correction for obscuration
r	=	population coefficient
LM	=	limiting magnitude
T_{eff}	=	observing time in hours, corrected for breaks
h	=	mean altitude of radiant during the watch period

The error in the ZHR is given as ZHR/√N. The population coefficient r is a characteristic of the brightness of the meteors for any particular shower, and its value for the eta Aquariids is about 2.4. It will be evident that the ZHR is critically dependent on both the limiting magnitude and altitude of the radiant. Looking at the $r^{(6.5-LM)}$ term, if the limiting magnitude is 6.5, the value of the term is 1, and no correction is made. As soon as the limiting magnitude drops to 5.5 however, the correction factor becomes 2.4, and for limiting magnitude 5.0 is already 3.7. Regarding the altitude, for a radiant altitude of 30°, the correction factor is 2.0, but quickly increases to 3.9 for an altitude of only 15°. From these factors it can be seen that a small number of observed shower meteors can lead to large ZHR values where the observing circumstances are less than ideal.

Since Figure 1 is based on global observations, and for the aforementioned reasons, one needs to be cautious about drawing definite conclusions from year to year. Nevertheless, the following may be inferred:

- Comparison with previous studies confirms the general rate at maximum in the range of ZHR=40-80.
- There is evidence of some enhancement of activity in the years 2005, 2006 and 2009, when rates were in the range ZHR=90-100.
- The enhanced rates in 2013 with ZHR~135 can be clearly seen.

Rate profiles of recent apparitions

The activity profiles for the years 2012-2014 and 2017 are shown together in Figure 2. The behaviour in rate profile for 2013 clearly stands out above the others, which are at a similar level and fall around the norm of the general maximum. It is also clear that the enhanced rates in 2013 were not the result of a single observer fortunate enough to witness the Earth's passage through a filament of dust, as was the case in 1993, but remained at a sustained high level, including at least the days before and after maximum.

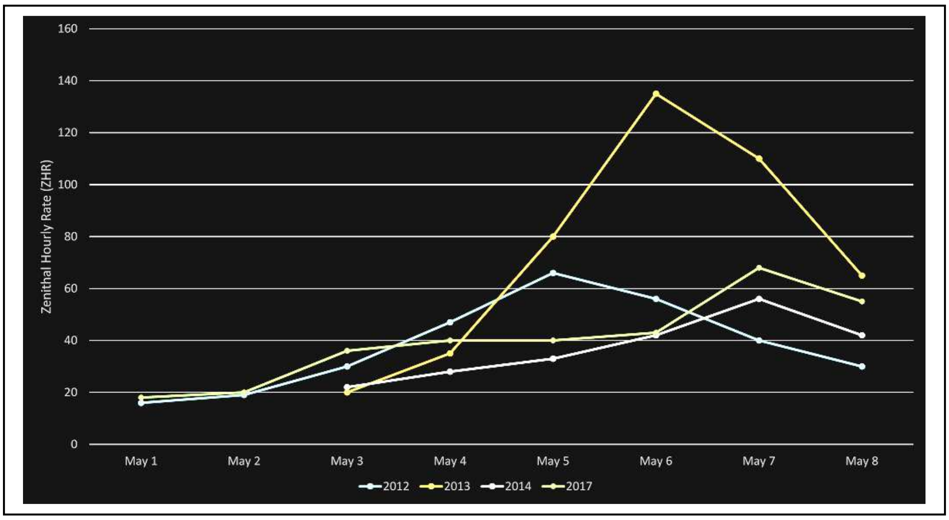


Fig 2. Recent activity profiles of the eta Aquariids Observations from IMO VMD.

Figure 3 shows the activity for the three mornings centred on the date of maximum based on observations by the author. To investigate variation within one morning, the observations were binned into 30 minute intervals instead of computing a single ZHR covering the whole session. The observations of the author are in good agreement with the global rates, and confirm activity was already at an elevated level on May 5, and significantly above normal levels on both May 6 and 7. Some evidence of filamentary structure in the stream may be present on the morning of May 5, when the ZHR reached 110 at May

5.09 UT followed by a drop to ZHR of only 65 half an hour later. Rates on the mornings of May 6 and 7 are however consistently high, attributed to passage through the stream of particles left behind by the parent comet in -910 and -1197 (Sato 2013).

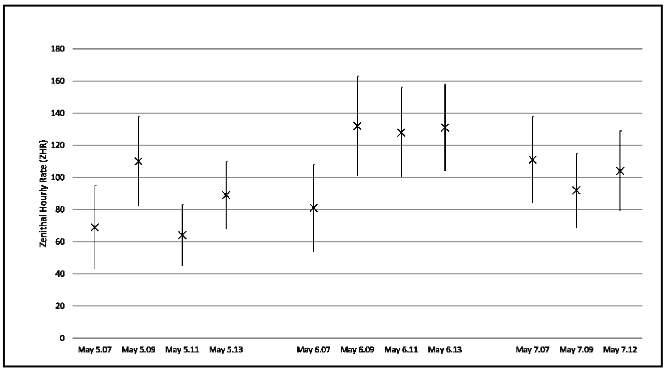


Fig 3. eta Aquariid rates in 30 minute bins for 2013 May 5-7 UT. Observations by the author.

Since the enhanced activity in 2013, observed rates have been at normal levels. The rate profile for 2017 is shown as Figure 4. The author managed observations on all mornings from May 1 to May 5, but the mornings of May 6 onwards were cloudy. Based on VMD observations the 2017 activity peaked at ZHR = 68$\pm$10 on 5 May, and after a brief recovery on May 7 dropped rapidly thereafter.

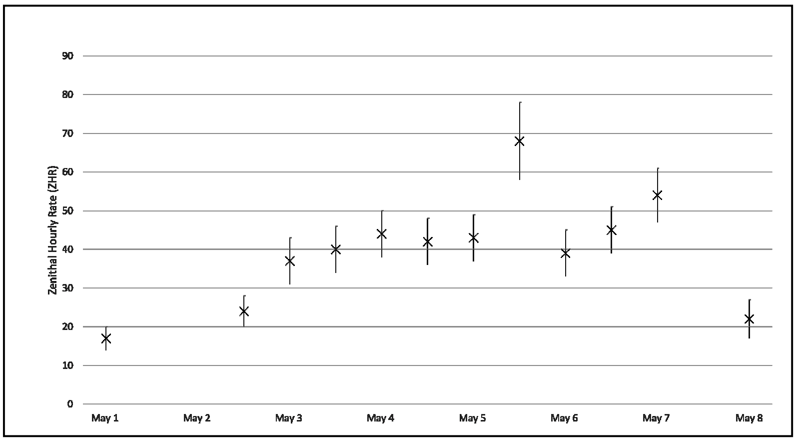


Fig 4. Rate profile for the 2017 eta Aquariids. Observations from IMO VMD.

Comparison of meteor brightness between 2013, 2016 and 2017 apparitions

With the clear increase in rates in 2013, the author was interested to compare the brightness of observed meteors to see if there was any apparent difference in particle size for that apparition compared to 2016 and 2017, both of which were normal apparitions. Results by date are shown in Table 1.

	2013 mean m_v	2013 n	2016 Mean m_v	2016 n	2017 mean m_v	2017 n
May 3	2.4	14	2.0	18	2.3	13
May 4	1.9	21	2.1	19	2.4	18
May 5	1.9	51	2.3	29	2.0	23
May 6	2.2	71	2.4	18	Cloud	--
May 7	2.3	58	2.1	14	Cloud	--

Table 1. Mean eta Aquariid visual magnitude m_v by date.

For the normal apparitions, the mean eta Aquariid brightness is in the range m_v = 2.0-2.4. For the 2013 apparition there is possibly a slight increase in brightness for the two mornings of 4 and 5 May, though the increased brightness of observed meteors is certainly not substantial. In any case meteor brightness on the mornings of 6 and 7 May were about the median of the normal brightness range. From this the author concludes that while there was a significant increase in observed meteor rates in 2013, the observed meteors were not significantly brighter than normal.

Conclusions

The eta Aquariids are the most active southern hemisphere meteor shower, and continue to surprise with the occasional years of enhanced activity. However they remain neglected by southern hemisphere observers, and would benefit from greater attention in order to better define their behaviour. The latest enhanced activity occurred in 2013, when rates reached ZHR = 135±16 on 2013 May 5. The meteors observed during the enhanced activity were not significantly brighter than normal. Since 2013 rates at maximum have remained at normal levels, the latest apparition being no exception, when rates reached ZHR = 68±10 on 2017

May 5. ASSA members can contribute to the understanding of this important meteor stream with improved observational coverage, and nothing more than the naked eye and dedication are necessary to make a significant contribution.

Acknowledgments

Rate profiles were generated using data courtesy of the IMO Visual Meteor Database.

References

Cooper T P, 1996, A Decade of Visual η Aquarid meteor observations, *WGN, The Journal of the International Meteor Organisation*, 24:5, pp157-161.

Cooper T P, 2013, The 2013 eta Aquariids from Bredell, *MNASSA*, Vol **72** Nos 11 & 12, pp183-189.

Dubietis A, 2003, Long-term activity of meteor showers from Comet 1P/Halley, *WGN,* ibid, 31:2, pp43-48.

Edberg S J, in International Halley Watch Amateur Observers' Manual for Scientific Comet Studies, first published 1983, NASA JPL.

Hajdukova M, Hajduk A, Cevolani G and Formiggini C, 1987, The P/Halley meteor showers in 1985-1986, *Astron. Astrophys.* **187**, 919-920.

Sato, M., communication posted to the '*meteorobs*' mailing list on 2013 May 4.

Wood J, Visual Observers Notes, May-June 1995, *WGN*, ibid, 23:2, April 1995, p38.

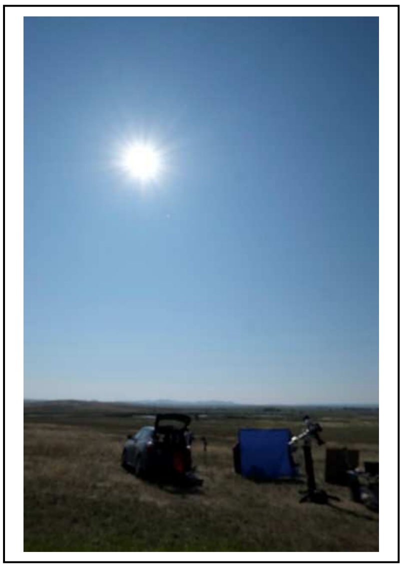
Observations of the Sky Brightness and Colour Changes during Total Solar Eclipse of 21 August 2017

Bruce Dickson. North York Astronomical Association
Director Cosmology Section ASSA

The author observed the solar eclipse from a location close to Glendo, Wyoming. He performed a number of experiments, one of which was recording the sky brightness as the eclipse evolved and measurement of the absolute sky brightness at mid-totality. The first of these was accomplished using a tripod-mounted Fujifilm X-E2 camera. While more frames were desirable, the internal battery only allows for 250 frames. The camera's built-in intervalometer was set to commence images a few minutes before first contact (16h24 UTC) and proceed at one frame per minute until a few minutes after fourth contact (19h12 UTC). Unfortunately, only 111 frames were usable before the sun escaped the frame.
A 12mm wide angle lens was installed and set at a fixed aperture of f/8. The intent was to minimise illumination fall-off (aka vignetting). Judging from the lens' datasheet [1] any error would be less than 0.1 stops or 7%. If higher precision was desired, flat fielding is relatively easy - albeit tedious. In order to maximise the available dynamic range, the exposure was allowed to vary. Proprietary image manipulation was minimised by recording raw images.

Dynamic range is worth discussing further. Most modern cameras have around 12-14 bits true dynamic range but they typically also have noise floors of 2 bits or more. There can therefore only be 10-12 bits of brightness information present in a single frame. This corresponds to a brightness ratio of 1024-2048. As will be seen, this is insufficient to capture the entire sequence. This is compounded when the image is converted to a DNG file (8 bits per channel) for further analysis.

The images below have exposures ranging from 1/1700 and 2.27 seconds respectively but each retains an acceptable signal-to-noise. The first is minutes before first contact while the second spans the commencement of totality. The third was made entirely during totality when the light extinction was 8000 times.


Figs 1,2 & 3.

An important caveat should be mentioned. While exposures are usually very well controlled by the camera hardware, few lenses offer accurate steps in the image brightness. It is good practice to stick to a single aperture and change the exposure. Even better results can be obtained using a fixed aperture lens – for example adapting a 1980's lens from an SLR. Caution is warranted because these lenses can produce a lot of ghosting.

Once the data was collected, the raw images were converted into DNG format using the (free) Adobe converter and examined using the Camera Raw pre-processor. This allows data from a modern camera to be interfaced with older versions of Lightroom and Photoshop.

Code was developed to read the image, determine the centroid of the saturated region (approximating the centre of the exposed part of the sun). It was determined that the sun-star – a photographic artefact caused by diffraction around the lens' aperture, extended approximately 400 pixels from the sun. Four 20 x 20 pixel blocks at a radius of 500 pixels were defined, above, below, left and right of the centroid. The mean RGB values in each of these blocks was calculated and scaled with the inverse of the recorded exposure. The signals from the four blocks were then summed and normalised with respect to the channel brightness in the images before first contact.

A second set of measurements was performed at a radius of 750 pixels. The signal for each channel is presented below.

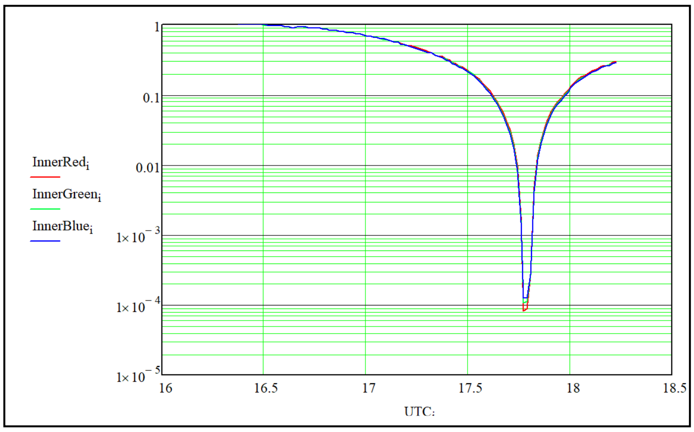


Fig 4. Normalised brightness at 500 pixel radius for the Red, Green and Blue channels

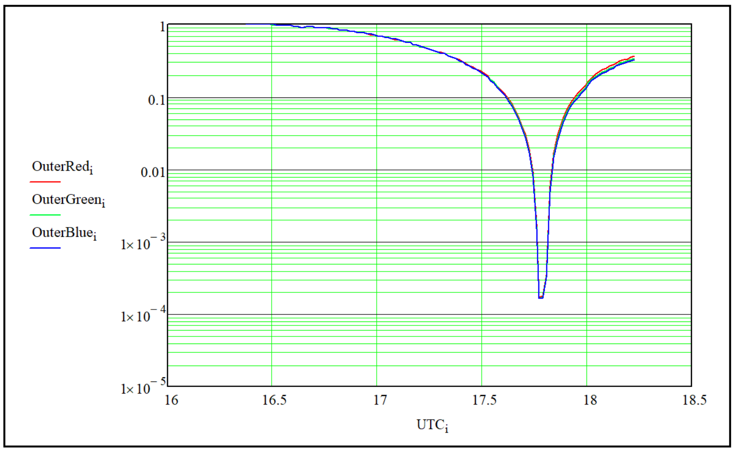


Fig 5. Normalised brightness at 750 pixel radius for the Red, Green and Blue channels

As can be seen in Fig. 4, it appears that the red channel exhibits significantly more extinction than the Blue or Green channels. This effect is not present in the measurements performed at larger radius which are recorded in Fig. 5.

It appears that red light was preferentially attenuated during the eclipse. The ratio of normalised red – to normalised blue light in each of the datasets was calculated and is presented below in Fig. 6.

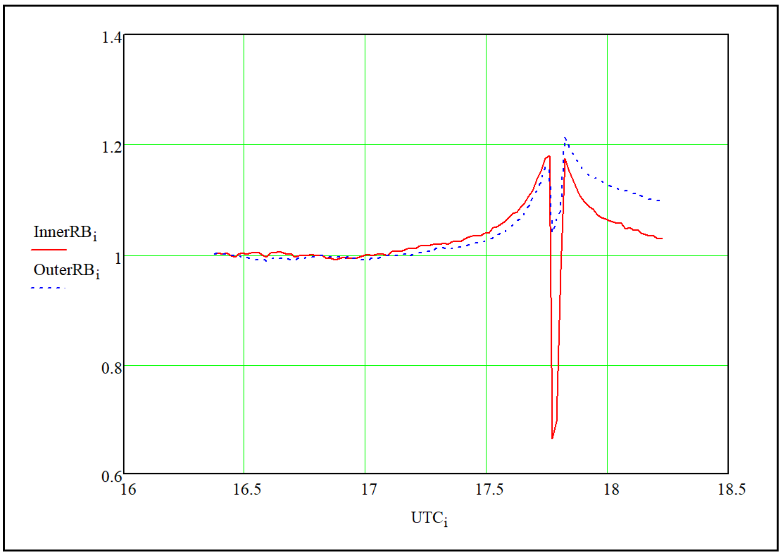


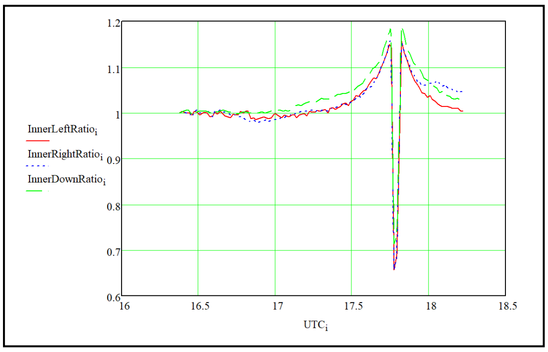
Fig 6. Normalised Red channel divided by normalised Blue channel at 500 and 750 pixel radius.

Fig. 6 shows an unexpected effect, namely that the ratio of red to blue light exhibits a strong peak before and after totality. During totality, the ratio exhibits a strong dip. We may conclude that shortly before C2 and after C3, that either blue light is suppressed or red light is enhanced or both. We can also conclude that between C2 and C3, either red light is suppressed or that blue light is enhanced (or both.)

The effect is apparent but less obvious in the outer ring of measurements.

The dip between C2 and C3 yields a clue. It was observed (and confirmed in photographs) that the Sun had one small prominence on its south-eastern limb and two small prominences on its south-western limb. A large prominence was visible on the western limb. Near mid totality, these prominences were not visible however they were obvious shortly after C2 and before C3. It is proposed that the reddening results from the photosphere being largely occluded while the prominences – part of the red chromosphere - remain partly visible. As the chromosphere is completely occluded, the only visible light in the sky is scattered from the extremely hot corona leading to a strong drop in the red-channel.

In order to support this, the ratios of normalised red-to normalised blue light left, right and below the Sun are presented for the inner and outer measurements.



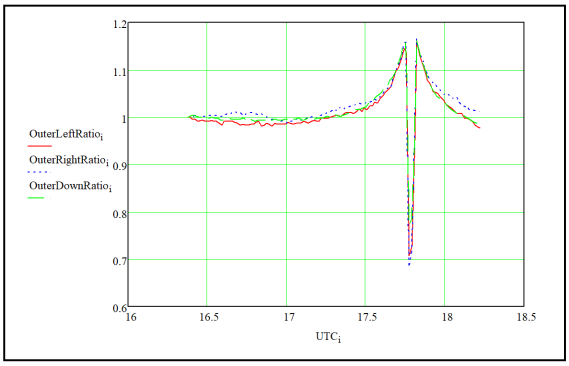


Fig 7 (left). Normalised brightness ratios at 500 pixel radius for the data sets left, right and below the sun.
Fig 8 (right) Normalised brightness ratios at 750 pixel radius for the data sets left, right and below the sun.

As can be seen in Figs. 7 and 8, the ratios of normalised red to normalised blue light are asymmetric on the left- and right- sides of the sun. These correspond to observations before C2 and after C3 when prominences were visible of the left and then right sides of the sun. The light curves are therefore consistent with the colour change being partially attributed to visible prominences.

The bulk of the signal peak is believed to originate from the chromosphere which extends outside the photosphere. The light curves measured below the centroid (in other words approximately south of the sun) appear largely symmetrical suggesting that the prominences play little role in the colour.

It should be noted that this explanation was viewed with scepticism by other researchers [2]. Their principal objection is that the chromosphere is very dim in comparison with the photosphere. They suggested that the observed reddening is a result of the 360° sunset observed during totality. It is the author's view that this would fail to explain the observed peaking before C2 and after C3. It would also fail to explain why red light is preferentially extinguished during totality.
Light extinction during totality

The zenithal sky brightness was measured at 12.8 magnitudes per square arcsec. A Unihedron SQM-L was employed which may imply the true sky brightness was ~12.6 magnitudes. Regardless, this measurement is several magnitudes brighter than an inner-city sky. The author noted that the sky was too bright to observe stars unaided however Regulus was visible in binoculars. Venus and Jupiter were easily visible to the unaided eye. One observer (David Cotterell) had a possible unaided sighting of Sirius.

Table 1 (below) presents a summary of measured light extinction that was recorded during totality

	Scaled Counts Before C1			Scaled Counts Mid Eclipse			Extinction during Totality		
Colour	East	West	South	East	West	South	East	West	South
Blue	341k	342k	378k	43.3	42.1	49.1	7868	8121	7696
Green	312k	309k	344k	34.6	33.4	39.8	9002	9248	8631
Red	278k	276k	301k	23.2	24.4	28.7	11390	11890	10470

Table 1 – Measurements of the averaged sky brightness in the inner ring
It is clear from the data recorded in the table that the extinction of red light is greatest in the measurements made to the east (left side) and right (right side) of the sun. The mean extinction of blue light was 7 895 (9.74 magnitudes) and of red light was 11 250 (10.13 magnitudes.)

Conclusions:

It is practical to use a digital camera to measure relative sky brightness changes over at least four orders of magnitude while maintaining an excellent signal to noise ratio.
The sky brightness dropped by nearly 10 magnitudes during totality.
There was a clear colour change in the sky measured ~15° east, west and south of the sun. This colour change, combined with sharp shadows from the barely visible photosphere, may explain the “strange lighting” that eclipse observers often report.

It is suggested that the colour change may be a result of variation in the ratio of visible light coming from the chromosphere compared with the photosphere.

Suggestions for improvement

The stop-motion movie proved to be entirely uninteresting. Science would have been better served by running the camera from 20 minutes before until 20 minutes after totality. This would have permitted an exposure every 10 seconds during the period where almost everything was happening. Obviously, frames before C1 and after C4 would be needed to record the extinction. Ideally, the image frame would be centred on the location of the sun at mid-eclipse and tracked so that the sun's position did not change with respect to the frame. This would greatly facilitate automated processing.

It might be interesting to compare the response of a H-alpha modified camera with that of an unmodified camera. Even better, a narrow band H-alpha filter could be employed in front of a monochrome camera and sequences covering photometric blue, photometric visible, photometric red and hydrogen emissions could be recorded. This would eliminate confusion created by the colours used in the camera sensor.

Acknowledgement

The author would like to express his gratitude to Dr Hong Wong of Gedex Systems for his assistance in coding the data extraction algorithms.

References

[1] Zeiss Touit 12 mm lens datasheet http://goo.gl/H19XcD
[2] Personal communication with Prof Jay Pasachoff et al.

Report back to ASSA on the European Planetary Science Congress 2017, Riga, Latvia

Clyde Foster – Director Shallow Sky Section

The European Planetary Science Congress (EPSC 2017) was held in the beautiful, historic city of Riga, Latvia from 18- 22 September.

This is one of the leading annual planetary conferences, and this year attracted 808 delegates from across the world. Although convened by Europlanet, with emphasis on work done by European assets and resources, worldwide co-operation and collaboration means that many multinational projects and missions were represented and reported on.

Having become a regular contributor to the Planetary professional-amateur collaboration databases, I was privileged to be invited to attend, and present, at the Congress.

My main interests over the last three and a half years since starting to image seriously has been Mars, Jupiter and Saturn, although some work has been done on other solar system bodies, and in discussion with the co-ordinators, it was proposed that I present on my extensive coverage of Mars over the period late 2015 to early 2017. During this period, with Mars well placed from the southern hemisphere, I was able to capture Mars data on approximately 250 nights, with just on 200 formal submissions being made to the various planetary forums/databases.

Fig 1. The author prior to his presentation; proudly representing the ASSA.

Throughout the week of the conference, at any time, up to six concurrent sessions were in progress, indicating the huge amount of work being done, and information being shared.

There was a small contingent of amateurs which had been invited and a specific amateur session scheduled for the Wednesday afternoon. I believe my presentation was well received, but it was very impressive, in watching the other presentations, to see the level of professionalism that is being achieved by the amateur planetary community. I was informed that I was the first amateur from outside of Europe to be invited and to be funded by Europlanet, which highlights just how much of a privilege it was for me to attend this event. According to the attendee country list I was the only representative from South Africa, although Botswana also had one (professional) representative, who I unfortunately did not manage to meet.

The professional presentations were, although highly technical, incredibly fascinating, not least of all “hot off the press” preliminary results from Cassini’s death plunge into Saturn only a week before the congress. I think my background as a Chemical Engineer certainly helped with some of the planetary atmospheric chemical composition aspects.

However, one of the aspects that really excited me was the use by the professional community of amateur generated data. I sat in on a number of presentations where the amateur planetary imaging community was acknowledged and warmly thanked for its contribution – very inspiring and encouraging for an imager such as myself. We, as an amateur community are able to effectively fill the gap in terms of monitoring the planets for any unusual actively when large and expensive professional assets such as VLT and Hubble Space Telescope cannot be deployed regularly.

Fig 2. L to R: Dr Glenn Orton (NASA JPL), Dr Michael Ravine (Malin Space Systems), the Author, Clyde Foster

The highlight for me was without doubt the opportunity to meet a number of professional and amateur contacts that I had, up until this point, only met online and in planetary forums. Not least of all Dr Glenn Orton, of NASA JPL, a veteran of many of NASA's most important planetary missions and who I have been interacting with whilst supporting the currently active Juno mission at Jupiter (see *MNASSA* Vol **76** Nos. 3 & 4 pp68 – 74). Dr Padma Yamarandra-Fischer of the Space Science Institute was another contact who I have been building a relationship with over the last few years, and was able to spend some good time with. She has played an important role in encouraging Pro-Am collaboration. There were many others (my apologies for not providing a list due to space), with fascinating, inspiring and enlightening discussions. A wonderful social evening was held at one of the local Riga folk clubs on the Wednesday evening, nicely timed after my presentation!

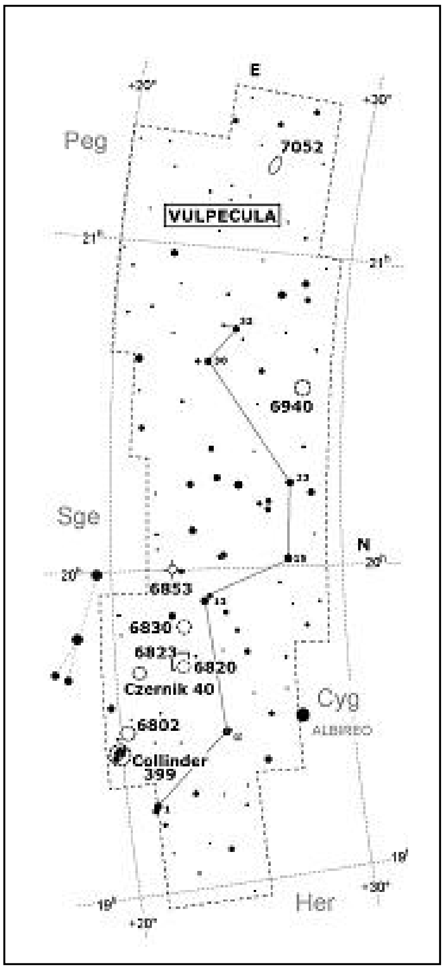
I was pleasantly surprised to be so warmly accepted and welcomed by both professionals and fellow amateurs alike.

I returned inspired and enthused to continue and build on the work that I am doing in this amazing field, humbled by the fact that we, as amateurs, quietly settled in our back garden observatories, are able to contribute to, and support, this amazing community of professional planetary scientists.

My sincere thanks to Marc DelCroix and Europlanet for the invitation to attend and present, and for the funding, without which it would not have been possible for me to attend.

Sky Delights: Why a Fox?

Magda Streicher



Not only is this the last constellation of 88 to have been named, but the name given to it is not exactly very flattering either. And yet, the celestial Fox brings exceptional objects to the fore to justify its place. Hevelius said that he wished to place a Fox in the sky because this animal is very cunning, voracious and fierce.

Fig 1. The constellation Vulpecula

We start at the tail end of the Fox with a surprising and unexpected object, the galaxy **NGC 7052** in the eastern part of the constellation. It is rather faint and has been described as a soft, slightly elongated shape with a hazy appearance; it looks as if it has a dust lane embedded almost edge on, and can be admired through a Hubble picture. It is almost certain to house a black hole somewhere in its centre. But do not be disappointed if you cannot glimpse this star city – the Fox will rise to the occasion with much more than a faint galaxy.

A rich open cluster, **NGC 6940**, half a degree in size, is riding on the back of our heavenly Fox. Keep faith in this constellation – it will get better. A large, sort of roundish swarm of stars of various magnitudes is situated not far from the border with Cygnus. Fainter members form short strings and knots and between members; dark, small areas can be glimpsed. A few brighter stars can be seen in the field on the rim of the star swarm.

One of the most celebrated planetary nebulae known to nearly all of us is **NGC 6853**, familiarly known as the Dumbbell Nebula. Charles Messier observed and catalogued this as the first nebula in 1764 when he spotted the Dumbbell and recorded it as object M27 in his famous list of objects. The planetary does not disappoint in any way. It is bright and large and presents itself as a prominent hourglass shape with a frosted light grey colour – in one word: magnificent! The two lobes that gave rise to its name are situated in a northern and southern position. With care, the central stars can be seen surrounded in a light transparent haze, with the southern part slightly brighter. M27's distance has been measured reasonably accurately as being about 300 light years away, with an age of around 20 000 years. Its surface is very hot, with a temperature of about 85 000 Kelvin. This high temperature releases tremendous amounts of ultraviolet radiation which excites M27's gases to glow. The nebula is composed of about 92 percent hydrogen, 7 percent helium and small amounts of oxygen, nitrogen, neon, sulphur and argon.

Fig 2. Dumbell Nebula M 27 (Courtesy Dale Liebenberg).

Not to upset the Fox too much, move towards the area indicated as its head with alpha Vulpeculae as its red, furious eye. A beautiful petite cluster, **NGC 6830**, can be found a few degrees east of alpha Vulpeculae, a rich patch of stars quite outstanding against the background star field. Every cluster tells a story, and this one brings to mind many thoughts because its shape consists more than a dozen stars, which could resemble a chicken's footprint, or an X shape formed by slightly brighter stars in its midst. A trapezoid of stars flanks the eastern part of the grouping with magnitudes between 11 and 13.

Slightly closer to alpha, two objects, **NGC 6820**, can be observed in one, although it is not an easy task to spot both. First, the clusters are a lovely rich grouping consisting of colourful pairs and star strings. The cluster is embedded in a veil of nebulosity which has been listed as the emission nebula **NGC 6823**, but the haze is only observable in very dark skies and with the use of a 0-III or nebula filter.

Asterisms are surely some of the most interesting star groupings to discover and observe. One such, named "the mini dragonfly", is close to the southern edge of the open cluster **Czernik 40**. It may be that the listed Czernick 40 and this asterism is one and the same object. However, it is a very realistic grouping which is worthy of its name, about a dozen outstanding stars in an east to west direction. The dragonfly's tail is formed by the brighter stars towards the west with the two magnitude 9 stars on the south-eastern top that mark the dragonfly's mismatched eyes. The curly wings run out with fainter stars towards the north-east and south-west. One stands amazed by the realistic appearances of groupings like this.

Close to the border with Sagitta towards the south-western part of the constellation is **NGC 6802**, an open cluster like no other. It was fascinating to observe NGC 6802 with its starlight reflecting a story-telling experience, the feeling of looking back from above on approaching a distant little town with flickering lights enveloped in mistiness. One could dredge into the reality of this little star town covered in a mist of rain, topped with a soft glow of light pollution and draped against the background of a distant dark mountain. One gets lost in the beauty of this elongated south to north grouping of stars sharing a close relationship.

Even more realistic is one of the best-known asterisms in the northern hemisphere situated virtually in the south-western corner of the Vulpecula constellation. The grouping, known as **Collinder 399**, or the Brocchi Cluster, is none other than the famous "Coat hanger cluster". What a lovely group of stars, which can be seen with the naked eye as a hazy patch in truly dark skies, and appears very realistically as a coat hanger with the aid of binoculars. The Persian astronomer Al-Sufi was the first to mark the group, in the 10th century, and in the early 20th century the astronomer Dalmiro Brocchi charted the group. In 1931 Swedish astronomer Per Collinder included it in his catalogue of clusters as Cr 399. It includes the stars 4, 5, and 7 Vulpeculae, and is one of the oldest clusters on record. There was some debate as to whether Collinder 399 is a real cluster or just a chance alignment of physically unrelated stars, but the Hipparcos satellite put it as just a chance alignment of stars.

Some Foxes might be furious and scary, but this heavenly animal shares its precious objects, partly obscured under its furry skin, in full glory with us.

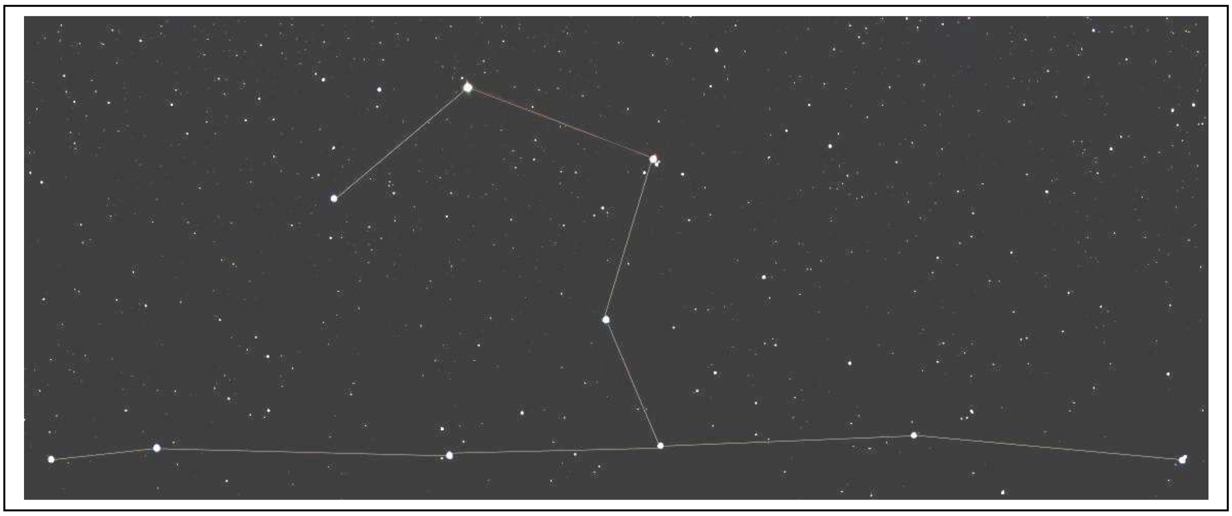


Fig 3. The Coathanger asterism (courtesy Dale Liebenberg)

Name	**Object**	**RA:**	**DEC:**	**Magnitude**	**Size**
Collinder 399	Cluster	19h27m.1	+21°06’.02”	8.8	58’x36’
NGC 6802	Open Cluster	19h30m.6	+20°16’.02”	8.6	3.2’x3’
Dragonfly Czernik 40	Asterism	19h43m.1	+21°11’.02”	9	20’x6’
NGC 6820	Emission Nebula	19h43m.1	+23°17’.02”		40’x30’
NGC 6823	Open Cluster	19h43m.1	+23°18’.02”	7.1	12’
NGC 6830	Open Cluster	19h51m.1	+23°’04’02”	7.9	6’
NGC 6853 Messier 27	Planetary Nebula	19h59m.6	+22°43’04”	7.6	7.3’
NGC 6940	Open Cluster	20h34m.6	+28°18’04”	6.3	31’
NGC 7052	Galaxy	21h18m.6	+26°27’04”	12.4	2.5’x1.5’

The **Astronomical Society of Southern Africa** (ASSA) was formed in 1922 by the amalgamation of the Cape Astronomical Association (founded 1912) and the Johannesburg Astronomical Association (founded 1918). It is a body consisting of both amateur and professional astronomers.

Publications: The Society publishes its electronic journal, the *Monthly Notes of the Astronomical Society of Southern Africa (MNASSA)* bi-monthly as well as the annual *Sky Guide Africa South.*

Membership: Membership of the Society is open to all. Potential members should consult the Society's web page assa.saao.org.za for details. Joining is possible via one of the local Centres or as a Country Member.

Local Centres: Local Centres of the Society exist at Bloemfontein, Cape Town, Durban, Harare, Hermanus, Johannesburg, Pretoria and Sedgefield district (Garden Route Centre). Membership of any of these Centres automatically confers membership of the Society.

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ISSN 0024-8266

mnassa

monthly notes of the astronomical society of southern africa

Volume 76 Nos 9 & 10 **October 2017**

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