ISSN 0024-8266

mnassa

monthly notes of the astronomical society of southern africa

Volume 81 Nos 7-8 August 2022

In this issue:

Cover Caption

C/2006 P1 (McNaught) imaged by Simon Walsh from Villiers in the Free State on 24 January 2007. See article on p133.

mnassa

Vol 81 Nos 7-8 August 2022

One hundred years of the Comet, Asteroid and Meteor Section

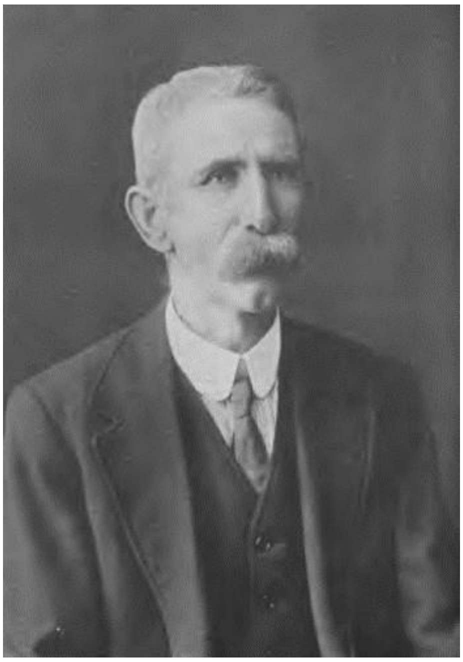
Tim Cooper, Director, Comet, Asteroid and Meteor Section

Preamble

The Astronomical Society of South Africa (ASSA) was formed on 1 July 1922, following the amalgamation of the Cape and Johannesburg Astronomical Associations. The history of the Comet and Meteor Sections is as old as ASSA itself, and they were formed as separate Sections following the Council meeting of 20 October 1922. Both Sections had already been in existence prior to the formation of ASSA, after the appearance of comet 1P/Halley in 1910 had led to considerable interest in astronomy, and ultimately the formation of the Cape Astronomical Association in 1912. Two observing sections were created, firstly the Meteor Section in 1913, followed by the Variable Star Section in 1914, both with William Reid as Director. During the years of the Great War (1914-18) two comets were discovered from Cape Town; on 24 November 1915, Clement Jennings Taylor discovered comet P/1915 W1, and on 12 June 1918, William Reid discovered comet C/1918 L1. Shortly thereafter, the Comet Section was formed in 1920 with William Reid as Director. Reid made further discoveries, those of comet C/1921 E1 on 14 March 1921 and comet C/1922 B1 on 20 January 1922. Following the formation of ASSA, the Comet and Meteor Sections were formed, with William Reid elected as Director of the Comet Section and Donald G McIntyre elected as Director of the Meteor Section. The history of the individual Sections from 1922 to 1962, and from March 1962 as the merged Comet and Meteor Section, is described here.

The Comet Section under William Reid, 1922-1928

William Reid's interest in comets was stimulated by the appearance of comet C/1874 H1 (Coggia) (Orchiston 2003), which he observed as a young boy from his native Scotland. In 1901 he emigrated to South Africa, and continued his observations from Rondebosch in the Cape. He was appointed Director of the Comet Section in 1922, and during his tenure as Director a further seven comets were discovered, three by Reid



himself (Figure 1), two by Theodore Blathwayt in Johannesburg, and one each by John F Skjellerup and George Edmund Ensor, the latter from Pretoria.

Fig 1. William Reid, Director of the Comet Section from 1922 to 1928, laid the foundations for the future of cometary observation and discovery in South Africa. Photo from Frontispiece, JASSA, 2(3): 89, 1928.

Reid presented annual reports on Section activities each year to the ASSA Annual General Meeting (AGM). However he was absent on 22 July 1925 due to ill health and his report was read instead by the Secretary. At that same meeting he was elected President of ASSA, and at the following Council Meeting he was thanked and re-elected Director of the Comet Section. Similarly, Reid was not able to attend the AGM held on 25 July 1926, and his report was again read by the Secretary. The Chairman 'expressed the Society's congratulations to Mr Reid, and also to Messrs Ensor and Blathwayt who had discovered new comets'. Following the meeting 'The Secretary was instructed to write informing Mr Reid thanking him for his past services, conveying the Council's best wishes for his restoration to health'. Reid did present his report to the 1927 AGM, reporting that no less than eleven comets were observed in the last year, including two new discoveries, by Mr Blathwayt and himself. It was to be his last report, and William Reid passed away on 8 June 1928. Reid's dedication as a comet observer had laid firm foundations for the Section. His discovery of six comets remains the highest number of discoveries by an individual from South Africa, a distinction he jointly holds with Mike Bester. In recognition of his contributions to observational astronomy he was awarded the Jackson-Gwilt medal of the Royal Astronomical Society in 1928, the year of his death.

Comet	**Discoverer**	**Date of discovery**
C/1922 W1	J F Skjellerup	1922 November 26
C/1924 F1	W Reid	1924 March 25
C/1925 F2	W Reid	1925 March 24
C/1925 X1	G E Ensor	1925 December 13
C/1926 B1	T B Blathwayt	1926 January 16
C/1927 A1	T B Blathwayt	1927 January 11
C/1927 B1	W Reid	1927 January 25

Table 1. Comets discovered 1922-1928, Comet Section, William Reid as Director

The Comet Section under A F I Forbes 1929-1944

There was no Comet Section report presented to the 1928 AGM, owing to the death of William Reid. It was therefore announced the next Comet Section report would cover two years. That responsibility fell on Alexander Forbes, who was appointed as the new Director of the Comet Section in 1929. Forbes initially arrived in South Africa in 1896, but returned to Scotland to study. He finally immigrated to the Cape in 1909, from where he observed and searched for comets with a self-built 8-inch reflector (Figure 2).

Fig 2. The 8-inch reflector used by Alexander Forbes. On the base can be seen the date 1922, the year ASSA was formed. Photo from (Kleyn 2002).

His first Comet Section report was duly presented to the AGM on 31 July 1929, and 'Mr Forbes was warmly thanked'. The following night Forbes discovered his first comet, P/1929 P1, as a magnitude 11 object in Microscopium. That comet turned out to be a periodic comet, now known as comet 37P/Forbes, and returns roughly every 6.3 years to perihelion. He made further discoveries in 1930 and 1932, the latter on 15 December when the comet was close to the bright star Fomalhaut. The comet was independently found two days later by G F Dodwell at Adelaide and was named comet Dodwell-Forbes. Alexander Forbes was joined by other amateurs in searching for comets, including Theodor Blathwayt who continued his searches with a 4-inch refractor and an 8-inch reflector, dedicating 130 hours to searching in 1931, though he did not add to his discoveries of 1926 and 1927, and passed away suddenly on 12 October 1932, aged 72. It would appear that with Forbes discovery in 1932, and the passing of Blathwayt in the same year, the age of the amateur comet hunter was in decline, and most discoveries in the coming years would be made by professional astronomers, mainly during surveys and searches for minor planets and variable stars. In between these professional discoveries however, two more comets were discovered by amateur astronomers, but both were discovered serendipitously while observing variable stars. H E Houghton and G E Ensor (Figure 3) discovered comet C/1932 G1 while observing the variable star T Apodis, and Reginald de Kock discovered comet C/1941 B2 while observing R Lupi (Figure 4).

Fig 3. Four South African variable star observers, from left to right A. W. Long, G. E. Ensor, H. E. Houghton, and W. H. Smith. Between them they made well over a combined 48,000 observations for the AAVSO. It was while observing the variable star T Apodis that Houghton and Ensor discovered comet C/1932 G1. Image reproduced with kind permission of the American Association of Variable Star Observers (AAVSO).

Fig 4. Reginald de Kock discovered comet C/1941 B2 while observing R Lupi. It was the last amateur comet discovery by an ASSA member until Jack Bennett's in 1969. Image reproduced with kind permission of the American Association of Variable Star Observers (AAVSO).

At the Cape Centre meeting held on 19 March 1941 there was a full discussion on comets, including reports of comet C/1941 B2 (de Kock), and also comet C/1940 R2 (Cunningham) which was well observed. However, Dr J. Jackson, then His Majesty's Astronomer at the Royal Observatory, Cape of Good Hope, confirmed the changing trend in comet discovery away from the amateur comet hunter to professional institutions.

Comet	Discoverer	Date of discovery
P/1929 P1	AFI Forbes	1929 August 1
C/1930 L1	AFI Forbes	1930 May 29
C/1932 G1	HE Houghton and GE Ensor	1932 April 1
C/1932 Y1	AFI Forbes	1932 December 15
C/1935 A1	EL Johnson	1935 January 7
C/1935 M1	C Jackson	1935 June 3
P/1936 S1	C Jackson	1936 September 15
C/1940 01	JS Paraskevopoulos	1940 October 8
C/1941 B2	RP de Kock JS Paraskevopoulos	1941 January 15 and 23
C/1941 K1	H van Gent	1941 May 27
P/1941 01	D du Toit	1941 July 18
C/1943 W1	H van Gent	1943 November 27
P/1944 K1	D du Toit	1944 May 16
C/1944 K2	H van Gent	1944 May 23

Table 2. Comets discovered 1929-1944, Comet Section, Alexander Forbes as Director

The method of finding comets had undergone considerable change, or rather amplification, during recent years. Comets were at one time found only by visual observation. Since a comet becomes rapidly brighter as it approaches the sun, comet-seekers searched the sky near the sunrise and sunset points with the result that most comets were near their maximum brightness when first observed. Photographic methods, however, made it possible to find comets while they are still faint and far away from the sun.

During 1942, W P (Bill) Hirst reported on 'The useful activities of amateur astronomers', but regarding comets he limited his comments to comet hunting, and regarding meteors he said 'are observed without telescopic aid and will therefore not be further considered'. In his Annual report of the Comet Section 1941-42, Forbes said, 'Compared to the stirring cometary events of last year, this year has been quiet. Only two new comets have been discovered' (duToit-Neujmin and Whipple). In 1943 the story was the same; 'This has again been a quiet year and no reports of comets have been received from South Africa. As far as your director knows very little sweeping has been done'. In 1942/3 Forbes served as ASSA President, and the topic of his Presidential Address was simply 'Comets' in which he noted:

This evening I wish to traverse some of the work we have been doing and are trying to do as the Astronomical Society of South Africa. My outlook is purely from the position of an amateur astronomer…The history of our Sections has shown that, with the *exception of the Variable Star Section, the Comet and the Zodiacal Light Sections, they have been more or less a one man operation - depending mostly on the efforts of one man. But in a society so small as ours it is difficult to organise a team, so we must do the best we can.*

He ends with what can only be considered a plea for more to become involved:

I have kept up a steady search for comets for from 18 to 19 years. I cannot keep it up indefinitely and I appeal to our younger members to come forward and maintain the continuity of the work so ably begun by Taylor, Reid, Blathwayt and Skjellerup. South Africa has earned for itself some reputation for comet discoveries. We have now 29 new discoveries to our credit, 22 of them by members of our Society. The work is not exacting, in fact, for those who are busy indoors with other work during the day, it is a relaxation.

Forbes last Report of the Comet Section was presented for the year 1943-44, when he reported:

Little activity has been manifested by the Comet Section this year. During the first half of the year a good deal of sweeping was done every month but since the New Year we are not aware that any member has been carrying on any methodical search. This is to be regretted because some comets might be slipping past without being seen. In the past, the observational side of the subject has been our strong point so we hope the work will be kept up by others.

Clearly, now in his early seventies, and with little comet observing taking place within his Section, Alexander Forbes had decided it was time for change.

Comet	**Discoverer**	**Date of discovery**
P/1945 G1	D du Toit	1945 April 9
C/1945 L1	D du Toit	1945 June 11
C/1945 X1	D du Toit	1945 December 11
C/1946 U1	MJ Bester	1946 October 31
C/1947 F1	MJ Bester	1947 March 24
C/1947 K1	MJ Bester	1947 May 18
C/1947 S1	MJ Bester	1947 September 25
P/1948 Q1	C Jackson	1948 August 26
C/1948 R1	EL Johnson	1948 September 1
C/1948 W1	MJ Bester	1948 November 24

Table 3. Comets discovered 1945-1948, Comet Section, Committee or E L Johnson as Director

The Comet Section run by Committee and E L Johnson, 1944-1948

At the Council meeting held on 9 August 1944, 'Mr Forbes had expressed his wish to resign the Directorship of the Comet and Zodiacal Light Section. It was decided not to appoint a Director of this Section, but in a motion proposed by Mr Hirst and seconded by Mr Krumm, it was decided that the observing sections be combined into one Observing Section to be directed by a committee, which was to include Mr Houghton and Canon Ford, the Directors of the present sections, and Messrs Davies, Hirst and Krumm, members of a local committee whose duty it was to canvas members in possession of telescopes with a view to recruit for the observing section'.

Despite the lack of amateur observations of comets, these were the heydays of comet discovery from South Africa, with twelve discoveries between 1944 and 1948. All were discovered by professional astronomers, nine of the twelve from Boyden Observatory, by Daniel du Toit and Mike Bester (Figure 5).

Fig 5. Daniel du Toit, at left, and Michiel (Mike) Bester, who between them discovered eleven comets from Boyden Observatory. Photo of du Toit credit to the du Toit family, uploaded to Wikipedia and made available under CC BY 4.0 license. Photo of Bester from Sky and Telescope, part of AAS Sky Publishing, LLC, February 1948 issue, page 86.

In September 1946 it was resolved 'that Mr du Toit of Bloemfontein (Harvard Observatory) be asked to form a Comet Observing Section, of which he would be Director. Mr du Toit was to be informed that the Council would make arrangements for the computing of orbits'. However, du Toit declined the position, and at the Council Meeting on 30 October 1946 'a letter from Mr du Toit declining the post of Director of the Comet Section was read to the meeting. Members were informed that Mr E L Johnson of Johannesburg had now accepted this position'.

Ernest Leonard Johnson was a staff member at the Union Observatory (Figure 6), and was actively involved in searching for asteroids. In all he discovered eighteen asteroids between 1946 and 1951, including one on 31 May 1948, which was later named 5038 Overbeek, in recognition of the doyen of ASSA observers Danie Overbeek. During these searches he also discovered four comets, the first C/1935 A1, followed by comets C/1948 R1, C/1949 K1 and C/1949 Q1. In his 'Report of the Comet Section for 1946-47', Johnson gave a list of comets discovered, including several observed by himself.

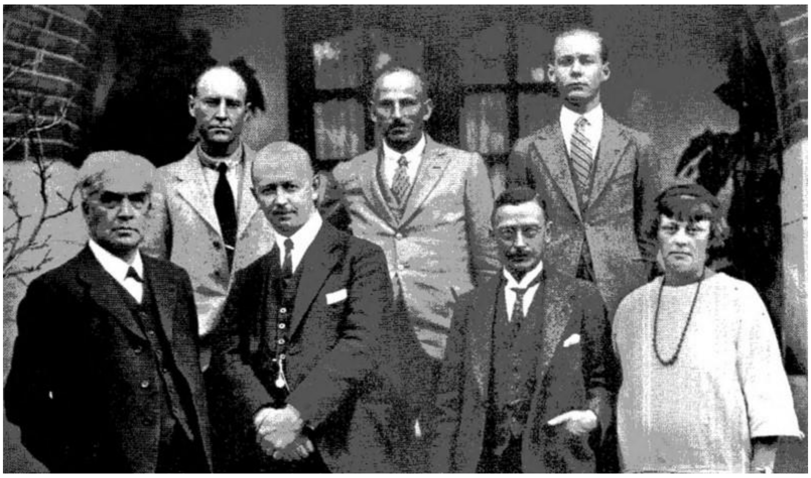


Fig 6. E L Johnson is in the back row on the left, along with H E Wood and W S Finsen, front row left to right are R T A Innes, Prof Georg Struve, W M Worsell and Ms S S Bosman. Photo ca 1926, from Vermeulen (2006).

Meanwhile, Alexander Forbes maintained his interest in comets, and in the November 1947 issue of MNASSA he published an article 'South Africa's place in cometary discovery', in which he noted:

It is interesting and instructive to look back over past records and to note what South Africa has contributed to cometary discovery. For the period January 1918 to December 1945, 80 new comets were discovered in the Northern and Southern Hemispheres. Of these, 29 came from the Southern Hemisphere, of which 26 are accredited to South African observers. While South Africa can be justly proud of this record, these figures would appear to indicate that about half the number of comets appearing in our Hemisphere are slipping by unobserved, assuming an equal distribution in both Hemispheres. Amateurs with suitable instruments in South Africa are urged to take up the search and study of comets and so not only maintain, but improve the place this country has earned in the discovery of new comets.

He continued:

The study of comets has taken on a new importance in the light of the recent achievements of radar in locating meteoric showers. The association of meteors and comets is now well established. I believe a great and interesting future is about to develop in regard to meteors and comets and those who get interested in the subject now will in the future have the satisfaction of having taken part in a great advance of science.

With this statement, Alexander Forbes was the first person to make a link between the activities of the Comet and Meteor Sections, which would ultimately be merged just a few years later. In the meantime, interest in comets was briefly heightened by the appearance of two very bright comets in 1947 and 1948. Comet C/1947 X1, also known as the Great Southern Comet, was first seen on 8 December as the sun set. Jackson reported 'This bright comet was seen by people all over the Union…as it became dark', and Paraskevopoulos said 'This spectacular object was first seen in South Africa…by practically everyone who happened to be out in the open under a clear sky'. The comet was extensively observed, sketched and photographed by both amateurs and professionals, and in his Report of the Comet Section for 1947-48, Johnson mentions van Biesbroeck's measurements of the double nucleus of the comet with the 26½'' refractor. In 1948, comet C/1948 V1, also known as The Eclipse Comet, was first seen during the Total Solar Eclipse of 1 November 1948, when the magnitude of the comet was estimated as –2. Again the comet was well observed, including by J. van B. Lourens and T.W.Russo, and Bill Hirst reported on 'The orbit of comet 1948l from Cape and Radcliffe Observatory places'. Further during 1948, Johnson listed five comets discovered during this period, but not a record of observations, and in Comet Notes, MNASSA September 1948, Hirst said 'Towards the end of August two comets were discovered in South Africa, one by C. Jackson of the Yale Southern Station and the other by E. L. Johnson of the Union Observatory'. Again both discoveries were made by professional astronomers.

The barren years of the Comet Section

From 1949 onwards it is not clear who was actually directing the Comet Section, and there appeared to be little activity, certainly among amateur astronomers. At the AGM held on 26 July 1950, there was no comet report tabled, although Bill Hirst indicated orbits had been computed. Similarly there were no comet reports presented at any of the AGMs held between 1951 and 1958, though in his Presidential Address in 1955 on the subject of 'The amateur in astronomy: past and present', Peter Kirchoff, describing work that amateurs can do, mentioned both comet and meteor observing. The principles he gave are much the same as are in use today.

comet magnitudes and nova search recommend themselves by the simplicity of their methods and of the equipment needed. The method of determining comet magnitudes consists of comparing the brightness of the comet with neighbouring stars by observing the field with out-of-focus binoculars. The blurred disk of the star lends itself better for comparison with the comet than the lightpoint in focus. Otherwise the same principles as in variable star work apply', and 'Meteors can be divided into two classes for the purpose of observation, naked eye meteors and telescopic meteors….The observer should have a good knowledge of the sky and some experience in estimating magnitudes.

Comet	**Discoverer**	**Date of discovery**
C/1949 K1	EL Johnson	1949 May 20
P/1949 Q1	EL Johnson	1949 August 18
C/1959 O1	MJ Bester	1959 July 26

Table 4. Comets discovered 1949-1959, Comet Section, no Director

During the ten years from 1949 there were only three new comet discoveries, all by professional astronomers. Indeed, at the 1958 AGM no reports for either Comet or Meteor Sections were presented. The time was fast approaching for change, and the two Sections to be combined into one, to be known as the Comet and Meteor Section.

The Meteor Section under Donald McIntyre, 1922-1926

Like Reid, Donald McIntyre also joined the Cape Astronomical Association, and following the formation of ASSA was appointed Director of the Meteor Section at the Council Meeting held on 20 October 1922. He delivered his report to the first AGM of the Society in 1923, which Reid supplemented by showing 'drawings he had made of curious trails from meteors he had observed telescopically'. At the 1924 AGM there was no meteor report tabled, but McIntyre was nevertheless re-elected Director of the Meteor Section. At the AGM on 22 July 1925, 'The report of the Meteor Section was read by the Director', and at the Council Meeting the following month 'Mr D G McIntyre was thanked and re-elected Director'. At the 1926 AGM held on 25 July, 'Mr McIntyre, the Director of the Meteor Section, had written explaining that owing to ill health he had not been able to prepare a report and regretted his absence from the meeting for the same cause'. At the following Council Meeting held on 16 August it was recorded 'After discussion it was decided that as this Section appeared to have little support from members it was not worthwhile to appoint a Director, no appointment was therefore made'. Attempts were made to revive the Meteor Section by Theodore MacKenzie between 1928 and 1930 but these again failed due to lack of interest (Smits 1960). Therefore, at this point the Meteor Section became inactive, and would remain so until 1946. While the early Meteor Section under Donald McIntyre had not succeeded, he would however leave a lasting contribution to the field of comets and meteors with his publication of 'Comets in Old Cape Records' (McIntyre 1949).

Resurrection of the Meteor Section in 1946

Following the years of inactivity after 1926, Alexander Forbes was the first to sow new seeds. During the AGM of 1943 he said 'efforts are being made to establish a meteor section. This is a most interesting subject and I hope it will succeed.' With regard to meteors he continued:

There is no doubt of the connection between comets and meteors. The leading theory is that when near the Sun a comet leaves a trail of meteors along its path. When the Earth in its orbit crosses this path a display of meteors may be seen coming from a radiant point of the sky where the comet's orbit is. I have said that a trail of meteors is left. This is speaking rather loosely. If meteors get separated from a comet they may reasonably be expected to precede the comet as well as follow it. This has been suggested but as far as I can find there are no certain records, though some are suspected to be a group of meteors belonging to and preceding a comet.

At about the same time, a series of three articles was published in MNASSA entitled 'Meteors and meteor observing' (Vol 2, p5, December 1942, Vol 2, p10, January 1943, Vol 2, p18, February 1943), including general instructions, rules for recording meteors and a meteor observing report form. These guidelines are very much in line with the procedures we use today for visual observing. At the Council meeting held on 4 September 1946, in addition to asking Mr du Toit to start a Comet Observing Section, 'It was also decided to ask Mr Venter to be Director of the Meteor Section. Venter evidently accepted the position as 'Mr S C Venter, the Director of the Meteor Section had written to ask whether the observations of meteors should be sent to New Zealand or to Olivier. It was decided to write to Olivier asking his advice on the matter'. The Olivier referred to was Charles P Olivier, who founded the American Meteor Society in 1911, and was a world authority on meteor science. In 1946 Venter published 'An expected meteor shower', in which he talks about the upcoming Giacobinids. The shower had shown an outburst in 1933 and was predicted to do so again on 9 October 1946. Venter correctly informed that the shower radiant is in the far north and consequently would not be well seen from South Africa. In an address to the Cape Centre on 9 October 1946, J C de Wet also spoke about the Giacobinids, and referenced an article in Die Burger by Dr Gawie Cillié quoting 'The probability that there will be much to be seen in this part of the world can be regarded as extremely slight'. Despite the full moon that night, the predicted outburst materialised and in the northern hemisphere rates reached 10,000 meteors per hour for a short while. While Cillié was correct in his statement, and there are no reports of observations from South Africa, it might have been expected the 1946 Giacobinids would have increased interest in observing meteors within ASSA, but alas in his Meteor Section report presented on 23 July 1947, Venter says:

'Meteor observing does not appear to attract as many disciples as other branches of astronomy. This is strange, because the observation of meteors is about the only line open to amateurs not possessing telescopes and the majority of amateurs fall in this class. Moreover, this is the only branch of observational astronomy in which a wide, unexplored field lies open to the amateur'.

He went on to say that, as no new members had joined, he was the only observer of meteors in South Africa. This situation persisted, and the AGM in 1950 recorded 'The Meteor Section report, presented by Mr Venter who continues to be the only observer in this Section, was read by Mr Krumm'. Nevertheless, Venter's continual efforts to popularise meteor observation began to bear fruit, and on 25 July 1951, Venter reported two new observers, J H Botham and Arthur Morrisby. At the Council meeting held on 12 September 1951, a letter from Venter was tabled asking for assistance in obtaining copies of maps for plotting, and on 6 February 1952, 'Dr Stoy reported Mr Venter's star charts had been duplicated and sent to Pretoria'. These maps would be put to very good use in the near future. At last with the Meteor Section on firmer foundations, Venter was able to report:

the Section maintained a steady accumulation of observations.' Besides the routine searches for new radiants, watches were also organised for the recognised showers as far as these were observable from South Africa…The Section cooperated with the ''Werkgroep Meteoren'' of the Netherlands Astronomical Society and the American Meteor Society as regards the Perseids. Special watches were organised in connection with the expected meteor shower from comet 1951a [in modern nomenclature C/1951 C1 (Pajdusakova)]. Over one hundred members of the public responded to appeals in the press in connection with fireballs…115 replies alone were received in respect of the great meteor which flashed half-way across central South Africa just after sunrise on the morning of the 30th January, and seen by observers in all four provinces. No new observers joined the Section…but one observer, Arthur Morrisby- unfortunately had to be written off when he joined the staff of the Royal Observatory. He made amends however, by giving his meteor camera to the Section. Number of hours spent on watches, J H Botham 111h25m; A Morrisby 11h41m, S C Venter 83h.

The visual observation of meteors totalling over 205 hours by three individuals is a considerable effort, and ASSA owes this new-found success to the dedication and perseverance of 'Science' Venter (as he was popularly known). That success was to continue, with many hours logged by Botham and Venter in 1952/3 and 1953/4, assisted by Messrs Garlock, and Jooste. By 1956 the number of observers had grown to nine, and included contributions by Venter and Botham, as well as Ian Brickett, Joe Churms and Roy Smith, members of the 'Observatory Associates', a group of enthusiastic amateur astronomers who were appointed by Finsen to help out at the Union Observatory (Figure 7).

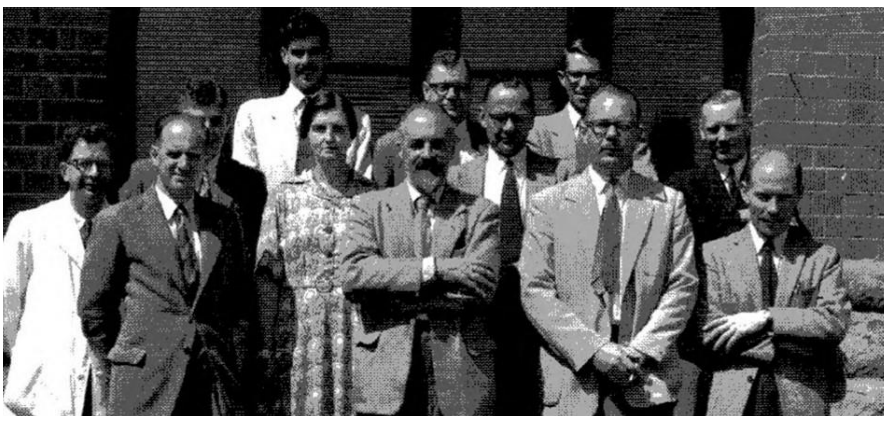


Fig 7. Union Observatory staff in the mid 1950s. J H Botham is on the far right of the middle row. Joe Churms is in the centre of the back row, with R W Brickett in the back row far right. In the front row can be seen Jan Hers, W H van den Bos and W S Finsen. Photo from Vermeulen (2006).

The contribution of J H Botham to meteor observation is noteworthy, not only for his dedication to visual observation of meteor showers, but also his observations of meteors using small telescopes. In 1960 he stated 'One of the problems connected with meteor research, which still seems far from being solved, is the rate of increase in the numbers of meteors with each succeeding step down the scale of magnitudes'. To answer this question, Botham began observing meteors with the 2'' telescopes used as part of the Moonwatch program. In doing so he extended the magnitude distribution of observed meteors to magnitude 8, and arrived at an increase factor of 2.5. This factor is known today as the population index, r, and is an important factor in the determination of the zenithal hourly rate (ZHR) of meteor activity. The population index describes how many more meteors can be expected moving from one magnitude class to the next fainter magnitude class.

The Meteor Section achieved a significant success on the evening of December 5, 1956. Activity from a previously unknown radiant at high southern ecliptic latitude was first observed from New Zealand at 10h10 UT (Ridley 1962). As darkness fell in South Africa the shower was still in progress, and sixteen persons managed to observe, including several organised in an 'emergency watch' by Botham. Experienced Pretoria amateur G Bebink observed between 18h00 and 22h00 UT and his ZHR of 102/hr is deemed the most reliable indicator of shower activity. The last person to observe activity from the shower was S C Venter, who observed until 22h45 UT, but more importantly he also plotted the paths of the meteors he observed on the gnomonic maps ordered five years earlier. The paths of 40 meteors plotted allowed determination of the radiant as RA = 15°, Decl. = –46°, in the constellation of Phoenix (Venter 1957). The shower is now known as the December Phoenicids, and comet D/1819 W1 (Blanpain) is the probable parent body. The 1956 outburst may well have been the result of the breakup of the comet in 1819, and while the occasional Phoenicid can still be observed, there are no further predicted outbursts until at least 2050 (Jenniskens 2006, p389).

Venter served as ASSA President in 1956/7, and in his Presidential Address 'The development of meteor astronomy' he gave an insightful view of the development of meteor science from its beginnings to the current time. His table of major meteor showers has sixteen entries, only five of which have declinations south of the equator, and these include the Hydrids and Virginids, Scorpius-Sagittarids and the Velaids, none of which would be considered major meteor showers today. That leaves the eta Aquariids as the sole major southern meteor shower. Just eight showers listed had known cometary parents. Finally he concluded:

I would like to say a little about meteor astronomy in South Africa. The first record of systematic meteor observations that I have come across is contained in the fourteenth report of the meteor section of the B.A.A. published in 1922. These observations were made by Messrs J Warren of Cape Town, Alan Cousins and Oeser [sic], both of Pretoria.

They observed 282 paths between them during the years 1921-1922. Eighteen southern radiants were deduced from these observations.

When the Astronomical Society of South Africa was formed in July 1922 it had a Meteor Section with D G McIntyre as its Director. The first appeal for observers appears in the second journal of the Society published in September 1923; the method of observation stated therein is substantially the same as the one we are using today. The first report appears in the fourth journal issued in October 1924. This report was mostly about a special shower seen by Mr W Reid on the morning of 1923 December 16. The next mention of the Meteor Section was in January 1930 when another appeal for observers was made. That was also the last mention of the Section that I could trace. This is a sad state of affairs for a country which affords such magnificent opportunities for this kind of work.

The merged Comet and Meteor Section

In November 1958, S C Venter wrote to Council expressing his wish to resign as Director of the Meteor Section, as his health had not been good. His resignation was accepted with regret, and Council responded with a unanimous vote of thanks for the work done in the past as Director of the Meteor Section. Shortly afterwards, the Comet Section also lost its Director, when on 15 May 1959, Alexander Forbes passed away. At the 1959 AGM there were no reports tabled for either the Comet or Meteor Sections, and the minutes noted 'Council says it hopes a successor to Venter will be forthcoming'. However, no immediate appointment was made and both the 1960 and 1961 AGMs passed without any reports from either of the Comet or Meteor Sections. A successor was finally appointed in 1962, and the answer was to be found in Venter himself. 'In a letter dated 6 January received from Mr. Venter, read by the Hon. Secretary, the disappearance of the Meteor Section was a shock to the writer. Mr. Venter would like an Observing Section started, for observing Comets and Meteors. Mr. Bennett of Pretoria and Mr. Venter had been doing a little on Comets in the past years. The Hon. Secretary was asked to inform Mr. Venter that Council would be pleased if Mr. Bennett or Mr. Venter would undertake to be Director of a Comet and Meteor Section'. Consequently in March 1962 S C Venter was appointed as Director of the new Comet and Meteor Section, and J C Bennett as Assistant Director.

At the Council meeting of 30 January 1967, a letter received from the Pretoria Centre was read 'intimating that Mr. J. C. Bennett had taken over from Mr. S. C. Venter as representative on Council. But on May 8, 'The Hon. Secretary was instructed to write to the Pretoria Centre that Mr. Bennett could not hold office as Centre Representative, as he was already a Member of Council in his own right, as a Vice-President. Another Representative should be appointed and his name communicated to Council as early as practicable'. Venter did not submit a report to the 1967 AGM held on 26 July. Then on 30 October 1967, in a letter from Mr [Harry] Kanowitz of the Pretoria Centre 'It was reported that Mr Venter, the Director of the Comet and Meteor Section, was not in good health, this in all probability accounting for the absence of observing reports. It was suggested that Mr Kanowitz should approach Mr Venter to ascertain whether the Centre could in any way assist that Section, and report back to Council'. Stephanus Christiaan Venter passed away on 26 January 1968. At the Council meeting on 5 February 1968 'Council wishes to place on record its deep regret at the passing of …Mr. Venter. The Secretary was instructed to ask Mr. Bennett for suitable material for an Obituary to be published later in MNASSA'. In May 1968 Mr Bennett was asked if he would assume the Directorship of the Comet and Meteor Section in place of the late Mr.Venter, to which he agreed and at the 1968 AGM Jack Bennett was confirmed as Director of the Section.

Fig 8. John (Jack) Caister Bennett, during a visit to the United Kingdom and at the telescope of Patrick Moore. Photo from Moore (1972).

At that same meeting Jack Bennett (Figure 8) was also elected President of ASSA. Jack's first year as Director was to all intents and purposes a quiet one. Indeed he said so himself:

The year under review has been one of the quietest on record. Only three comets came within range of small telescopes….. Very little was done about meteors, the only planned observation period being spoilt by bad weather. A report of a possible daylight meteor having been seen in Zululand appeared in MNASSA 28 (May 31st) page 44. Amateurs interested in observing comets and meteors are asked to get in touch with the Director of the Section.

But the fact remains that Jack had already started his own search for comets, and in the process made a serendipitous discovery of supernova 1968L in the galaxy M83 on 16 July 1968, the first extragalactic supernova to be discovered visually by an amateur astronomer. In the process of his comet searches, Jack noted many objects which he swept up, and due to their comet-like appearance in his telescope, needed to be checked and double checked to rule them out as possible new discoveries. To avoid duplicating these efforts, he prepared a list of Comet-like objects south of the celestial equator (Bennett 1969), followed by a Supplementary list several years later (Bennett 1974). Today we know this list of objects as the Bennett Catalogue, and consists of 152 deep sky objects 'which appear comet-like through a 5-inch telescope'. ASSA's Magda Streicher and Australian deep sky observer Jenni Kay produced a printed version of the

Bennett Catalogue in 2008 together with Bennett's original list, his biography and obituary, and Magda's and Jenni's extensive observations and sketches of each of the 152 objects (Kay and Streicher 2008). Jack Bennett should have delivered his Presidential Address at the 1969 AGM but was not present. Instead Joe Churms asked Mr Bentley to read the Presidential Address of Mr Bennett which was entitled 'Comet Hunting in Southern Skies'. The Address was given before Jack had discovered his first comet, and he went on to say:

Searching for comets has been likened to hunting for a needle in a haystack. In actual fact it is for the most part like looking in a succession of haystacks for a needle that isn't there! May I conclude with the advice of Leslie Peltier to all comet-seekers. It is short and to the point: "Keep looking! "

Finally, after 333 hours of searching, he found his first comet as an 8.5 magnitude object in Tucana on 28 December 1969, the first ASSA amateur discovery since de Kock's nearly three decades earlier. Comet C/1969 Y1 would become one of the brightest comets of the 20th Century and was a fine object visible to the naked eye with a long tail. He found his second comet (C/1974 V2) on 13 November 1974, having spent a further 482 hours since discovering his first (Kronk et al 1999). By now Bennett was not alone, and was joined in searching for comets by Jose Campos, who achieved his own success with the discovery of comet D/1978 R1 (Haneda-Campos) on 1 September 1978. That discovery was further recognised in 1985 when during a visit to Portugal Jose received the award of the Order of Henry the Navigator from General António Ramalho Eanes, President of Portugal, and was made a Comendador of the same Order. Jose was the last amateur astronomer to discover a comet from South Africa.

In his later years, Jack Bennett suffered from arthritis, which severely limited his ability to take his telescope outside to observe, especially in the cold dark winter mornings. His last report was presented to the AGM in July 1986, which noted 'Jack C Bennett resigned after 16 years as Director of the Comet and Meteor Section of this Society and as from October 1985 a new Director (J Campos) was appointed by the Council'.

Comet	**Discoverer**	**Date of discovery**
C/1969 Y1	JC Bennett	1969 December 28
C/1974 V2	JC Bennett	1974 November 13
D/1978 R1	J da S. Campos	1978 September 1

Table 5. Comets discovered 1969-1978, Comet and Meteor Section, Jack Bennett Director

Fig 9. Jose Campos, Director of the Comet and Meteor Section 1985-1992, seen at the First ASSA Symposium held in Cape Town during June 23-25, 1992. The ASSA Symposium was first convened at the suggestion of Jose. Behind him on the left is Danie Overbeek. Image from MNASSA 51, p38.

Jose Campos was the ideal person to take the Section forwards. He was the only person apart from Jack Bennett who was actively searching for new comets at the time, and he was an active meteor observer too. His term as Director coincided with the long-awaited appearance of comet 1P/Halley, and in February 1985 he was invited by Stephen Edberg from JPL and Coordinator for amateur observations as part of the International Halley Watch (IHW) to act as local Leader of the Real Time Observation Network and Correspondent for Southern Africa. As a result of Jose's initiatives the comet was well observed and ASSA members made a significant contribution to the IHW program. Regarding observation of meteors however, in his 1987 report Jose said 'very little activity has been reported regarding meteor showers. With the exception of Timothy Cooper and R Thompson, the coverage of meteor showers is virtually non-existent'. By the following year, and as a result of a number of observing circulars sent to prospective members, the number of individuals submitting observations of comets and meteors grew to over two dozen, though the majority still favoured observing comets. But interest in observing meteors had at least been stimulated. In June 1988 Tim Cooper published results of observations of the minor Ophiuchid stream (Cooper 1988), which included a combined observing session organised with several members of the Natal Centre, including Jose Campos. That report would provide an important link in the future of the Section, and relations with the International Meteor Organisation (IMO). At the 1989 AGM Jose reported 'After many years of virtual neglect on meteor observation, the keen interest shown in 1987 was again visible in 1988'. Jose Campos was ASSA President in 1990-91, and during his Presidential term he suggested ASSA hold a regular Symposium. As a result the first ASSA Symposium was held in Cape Town in June 1992, and was well attended by more than 80 people. To date eleven Symposia have been convened. It was also as a result of a suggestion by Jose that the Historical Section was formed in 1992, following which Jonathan Spencer Jones was appointed as Director and tasked with establishing the Section's activities. Towards the end of Jose's tenure as Director, he said 'Halley's comet has now come and gone and perhaps what we need now to stir up interest once more, is a great comet such as the one of 1882'. The appearance of another bright comet would be realised with the appearance of comet C/1995 O1 (Hale-Bopp) just four years later.

The Section since 1993, the inclusion of asteroids, and modernisation

During late 1992 Jose Campos took the decision to relocate to his native Portugal; he announced 'with regret in early November I notified ASSA and Council of my resignation as Director of the Section. Following my proposal to Council, for my successor…I am extremely pleased that Council has agreed to appoint Timothy Cooper, an experienced observer, as the new Director of the Comet and Meteor Section from 1993 onwards'. Tim Cooper's interest in comets started when he was at school, and predictions were being made about the 'comet of the Century'. Comet 1973 E1 (Kohoutek) was predicted to reach magnitude –5 or brighter and possibly be visible in daylight. In the event the comet underperformed, but was followed by another bright comet, C/1974 C1 (Bradfield) shortly afterwards. These comets brought Tim into contact with Jack Bennett, who nurtured his interest in both comets and meteors, even acting as guest speaker at an astronomical gathering organised by Tim in 1979 (Figure 10).

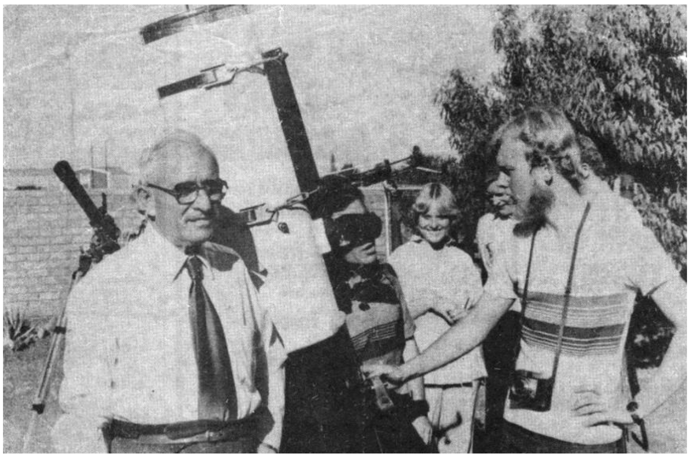


Fig 10. Jack Bennet in discussion with Tim Cooper in 1979. The occasion was an astronomical gathering held in Sasolburg, and Jack was a guest speaker. Here they are discussing Tim's homemade 8-inch, fork-mounted Newtonian reflector, on top of which can be seen the camera mount for a video camera, used to make recordings of the Moon. Jack commented that the video setup could ideally be used to make accurate lunar occultation timings.

On taking over the reigns as Director, Tim immediately put plans into place to increase interest in observing comets and meteors, including greater cooperation with overseas bodies, issuing a quarterly newsletter detailing observations required on specific comets and meteor showers, and publishing observations received from members in MNASSA. At the suggestion of Paul Roggemans, who had seen Tim's published observations of Ophiuchid meteors in 1988, he joined the International Meteor Organisation (IMO) as voting member in 1993, and following correspondence with Daniel Green acted as Observations Coordinator for Southern Africa for the International Comet Quarterly (ICQ). In this way he ensured that observations made by ASSA observers were effectively captured in the relevant international databases.

The Section became engaged in some interesting projects in the first few years of the 1990s. In July 1994, Comet D/1993 F2 (Shoemaker-Levy 9) impacted with Jupiter, and in preparation for the impacts by the numerous fragments an observing guide was prepared (Cooper 1994) which Prof. Walter Wargau published as a bound Research Report of UNISA. The impacts of the fragments between 16-22 July 1993 kept us spellbound, as each dark spot rotated into view and gradually dispersed over many days, as captured for example in a series of nightly sketches by Sonia Itting-Enke in Namibia. On the meteor front in early July 1995, Tim was contacted by Dr David Block (University of Witwatersrand) who had been approached by NASA meteor scientist Dr Peter Jenniskens who wanted to conduct observations of a potential meteor shower from an unknown long period comet. An outburst of kappa-Pavonids was observed from Australia in 1986, and Peter had predicted a possible return in 1995 (Jenniskens 2006, p181) with any activity predicted to occur during the night time hours from Southern African longitudes. ASSA members set up two observing stations and Peter joined us having brought several camera platforms with rotating segmented disks used to determine meteor velocity and duration (Figure 11).

Fig 11. Setting up the cameras with rotating choppers in preparation for the kappa-Pavonid meteor shower return in 1995. Left to right are Tim Cooper, Mauritz Geyser, Marianne Barendse and Louis Barendse (all Pretoria Centre). Image reproduced with kind permission from Jenniskens (2006).

In the event no repeat outburst of kappa-Pavonids was observed, but ASSA nevertheless gained perspectives on new observing techniques. Interest in comets remained high at this time with the appearance of Comet C/1995 O1 (Hale-Bopp), which despite being out of sight at its best, was well observed by members of the Section (Cooper 1998). Notable amongst these was Mike Begbie from Zimbabwe, who made over 300 visual observations and many excellent sketches of the comet (Figure 12).

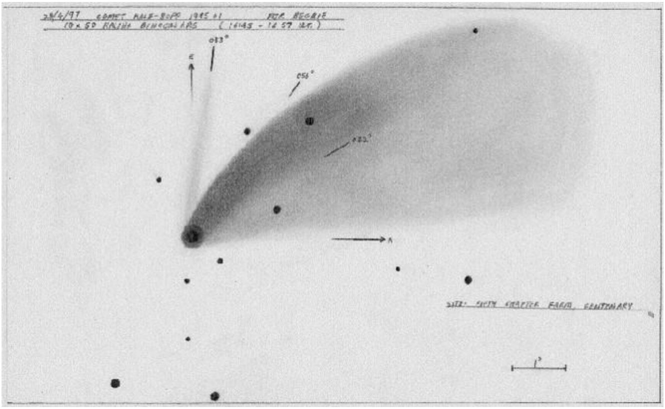


Fig 12. Comet 1995 O1 (Hale-Bopp), pencil sketch by Mike Begbie on 28 April 1997. In addition to many pencil sketches, Mike made over 300 visual observations of the comet from Zimbabwe.

Nowadays, powerful professional surveys have almost put the amateur comet hunter out of business, and there is a growing number of comets bearing the name NEAT, LINEAR, PanSTARRS and ATLAS. This includes instruments in Southern Africa, and so the first comet discovered from South Africa since 1978 was Comet C/2015 G2 (MASTER), discovered using the MASTER-SAAO telescope at Sutherland on 7 April 2015. The most recent comet bearing a South African name was Comet C/2020 S3 (Erasmus), named after Dr Nic Erasmus who discovered the comet on images taken on 17 September 2020 using the ATLAS instrument at Sutherland. That telescope is now fully functional and active in discovering new asteroids and comets. Nevertheless there remains an important place for the amateur comet observer in Southern Africa. Several techniques have advanced the study of comets and meteors; for example conventional film imaging has been replaced by digital imaging using CCD and DSLR cameras, with attendant software enabling powerful post-image processing techniques which give amateur astronomers the capability to do accurate photometry and astrometry, and even spectroscopy. A comet which was well observed both visually and by imaging was C/2006 P1 (McNaught), which allowed a thorough study of the brightness behaviour (Cooper 2007) and development of the tail features, or synchronic bands, which were prominent in this comet (Figure 13).

Fig 13. Comet C/2006 P1 (McNaught) imaged by Simon Walsh from Villiers in the Free State on 24 January 2007. The image shows the complex structure of synchronic bands, streams of particles which left the nucleus at the same time and left behind by the comet over a period of several days. Such images can be used to accurately measure the positions and motion of cometary features with time.

Most recently, Comet C/2021 A1 (Leonard) was similarly well observed with a variety of techniques which allowed a detailed study of the comet during the short period it was well placed from our location (Cooper and Coronaios 2022).

In the past 30 years, ASSA has made important contributions to the study of the eta-Aquariids meteor shower. Whereas the shower had previously been neglected, we have now contributed visual observations to the IMO Visual Meteor Database (VMDB) every year since 1993. These observations have been instrumental in helping elucidate the properties of this dynamically important meteor stream, one of two associated with comet 1P/Halley. Also starting from 1992, Tim Cooper initiated the Southern African Fireball Catalogue (SAFC) with the view to investigating and documenting every fireball reported to ASSA and making the data available for reference and analysis. Since many of these events are observed by members of the public, the process involves separating out those which are clearly not meteoric in nature, including (very often) aircraft contrails, space craft debris, artificial satellite movements, bright planets, and even Chinese lanterns! Once it is sure the event meets the criteria to be classed as a fireball (bright meteor with magnitude equal to or brighter than −4) more details are obtained from the reporter to determine the trajectory and possible radiant or shower association. To date, the SAFC documents well over 400 reported and confirmed fireballs, as well as 57 historical fireballs reported prior to 1992. One notable event was the impact of asteroid 2018 LA on 2 June 2018, which was widely seen over Southern Africa, and analysis of several videos enabled location of a strewn field for meteorites in the Central Kalahari Game Reserve of Botswana (Cooper 2021a). A subsequent search of the indicated location discovered several fragments now known as the Motopi Pan meteorite (Figure 14), and as part of a team involving NASA's SETI Institute, ASSA gained valuable experience in determining fall locations of meteorites. Analysis of the recovered meteorites enabled tracing the origin of 2018 LA to asteroid 4-Vesta (Jenniskens et al, 2021a).

Fig 14. Bright bolide from asteroid 2018 LA on 2 June 2018, left hand panel is video footage from one of six videos which were triangulated to determine the strewn field location for meteorites; upper right panel is the team which located 22 fragments of the Motopi Pan meteorite, standing at left is Tim Cooper, and crouching at right is Dr Peter Jenniskens; lower right panel is the first fragment discovered from asteroid 2018 LA, image reproduced courtesy of Dr Peter Jenniskens, NASA Ames and SETI Institute

As early as 2013, Tim Cooper had discussed the possibility with Dr Peter Jenniskens (NASA Ames and SETI Institute) of setting up cameras to continually monitor meteor activity. An opportunity arose to test the feasibility when possible meteor activity was predicted from Comet C/2015 D4 (Borisov) as the Earth crossed the orbit of the comet on 29 July 2017. Two camera arrays were set up by Oleg Toumilovitch and Tim Cooper using Watec 902H2 Ultimate low light video cameras in an attempt to capture meteor paths and triangulate to find their orbital details and radiant position. In the event the predicted shower did not materialise, but the arrays were used and expanded later to form the Cameras for Allsky Meteor Surveillance (CAMS) South Africa network (CAMS@SA), part of the global CAMS network. As of May 2022, CAMS@SA has captured more than 30,000 meteor orbits and has participated in the discovery of several new southern meteor showers, as well as the confirmation of some previously suspected showers. Most recently CAMS@SA participated in detection of meteors from a new shower, debris from a comet discovered from the Cape 135 years earlier. On the night of 26 September 1886, William Finlay was at the eyepiece of the 7-inch equatorial refractor at the Cape Observatory when he discovered the comet which bears his name. Now known as comet 15P/Finlay, it is a short period comet which returns to the Sun's vicinity every 6.5 years. Historically the comet has been faint at each return, but during the 2014/5 return it underwent an outburst, reaching magnitude 7, and ejecting large quantities of dust into its environment. Earth was predicted to cross the dust stream from that outburst during the night of 6/7 October 2021, possibly resulting in visible meteors. Activity indeed occurred close to the predicted time (Jenniskens et al 2021b), and despite the time of peak activity around 01h UT not favouring South Africa, CAMS@SA did manage to capture some shower members, and a few meteors were observed visually by Tim Cooper before the radiant set. In addition, activity was detected a few days earlier from the 1995 ejecta from the comet (Figure 15).

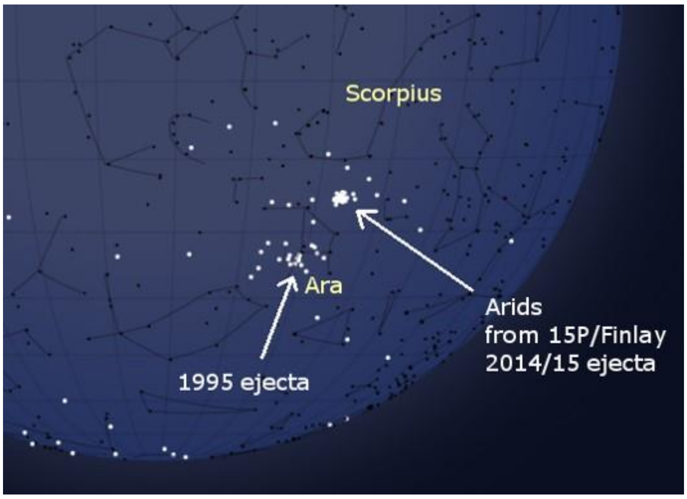


Fig 15. First detections of Arid meteors from Comet 15P/Finlay, showing radiant positions for particles ejected during the 1995 apparition and the 2014/15 outburst of the comet. Black dots are stars, white dots are radiants of detected meteors, clustered are shower meteors, outliers are sporadic meteors. Diagram from (Jenniskens et al 2021).

Finally, a few words should be said about asteroids. Historically, visual occultation timing of stars by asteroids, in order to determine their size and shape, was carried out by the Planetary Occultation Section led by Danie Overbeek. Over the years several successes were realised by a few dedicated amateurs using small telescopes and voice recorders on which commentary was recorded along with an audible time signal. In 1988, after the passing of Arthur

Morrisby, the Lunar, Grazing and Planetary occultation sections were amalgamated into a single section, the Occultation Section. The work as Director passed to Brian Fraser, but later the number of observations diminished as it became harder to obtain a suitable time signal and the program was disbanded. Since 2009, asteroids were incorporated into the Comet and Meteor Section. Attempts were made in 2015 to start the ASSA NEO Watch program, in support of NASA's Asteroid Grand Challenge which involves detecting all near earth objects (NEOs) larger than 100 metres, characterising them and mitigating risk from those objects. Unfortunately there was little response and despite some initial trial runs by Chris Middleton, Paul Ludick and Tim Cooper the project was concluded in June 2016. But the need for observations to determine asteroid light curves from which rotation rates and aspect ratios can be determined, and of asteroid occultation timings to determine size and shape still exists. With the advent of low light video cameras that can be synchronised to GPS time signals, as well as advances in more sophisticated computerised telescopes and mounts, it is hoped that the observation of asteroids will contribute more to the activities of the Comet, Asteroid and Meteor Section in the future.

As was historically the case, the number of active observers nowadays remains low. In recent times, apart from the Director, two observers have continued to provide observations over a long period. Magda Streicher has spent many hours observing meteors, including in September 2002 when she observed meteors from the shower now confirmed as the September upsilon Taurids (Cooper 2021b). Kos Coronaios has produced visual observations and excellent images of many comets over the years, and has also been instrumental in coordinating reports of fireballs for inclusion in the SAFC. Both Magda and Kos have set excellent examples of what can be achieved by dedicated amateur astronomers, and it can only be hoped that more young amateurs will become involved.

Conclusions

The Comet and Meteor Section is as old as ASSA itself, existing initially as separate Sections, but merged from 1962 to form a single Section. In that time the Section has had eight different Directors. Both Sections suffered from some period of inactivity, notably the Meteor Section between 1927 and 1945, and the Comet Section between 1948 and 1962. During the past century there was seldom more than a few dedicated observers, who nevertheless have made many lasting contributions to the discovery and observation of small solar system bodies, the debris left over from the formation of the solar system itself. With the advent of modern instrumentation and powerful new techniques available to the amateur astronomer, there is much we can contribute. Moreover, Southern Africa occupies an important position geographically, both from our southern hemisphere viewpoint, and the narrow range of longitudes within our region, especially important in the case of time-critical observations. As was the case on several occasions in the past, the current Director makes a further plea for more members to observe comets, asteroids and meteors and extend the proud ASSA legacy of the past 100 years into the future.

Acknowledgements
I would like to thank the following who provided information in support of this article. Chris de Coning, Director of the Historical Section, for providing the link to the scanned minutes of Council Meetings and AGMs of the Society. Beverley Lawrence of Chris van Rensburg Publications (Pty) Ltd for permission to use the images in Figures 6 and 7. Carmel Ives for perusing the archives at the Johannesburg Centre for old MNASSA articles, in particular Venter's records of observation of the Phoenicid meteor shower in 1956. Sara Beck of the AAVSO, who kindly provided the images used in Figures 3 and 4. Finally, without observers the Section could not exist, and all those observers who contributed to the activities of observing comets, asteroids and meteors in the past are heartily thanked.

References
Many facts were obtained from the minutes of Council Meetings and Annual General Meetings, available at http://assa.saao.ac.za/sections/history/assa-archive/national_council/. Reports of comets and meteors covering the period 1940 to 1954 were also obtained from Monthly Notes of the Astronomical Society of South Africa, Volumes 1 to 15 condensed, edited by and prepared under the direction of P. A. T. Wild, and copyright ASSA 1980. Details of comet discoveries listed in Tables 1-5 are from Maik Meyer's Catalogue of Comet Discoveries, 2002 edition, available on request at www.comethunter.de. Additional references used in this article follow:

Bennett, J. C., (1969), Comet-like objects south of the celestial equator, in Presidential Address 1969, *MNASSA* **28**, pp85-88.

Bennett, J. C., (1974), Some objects of interest in the southern sky, *MNASSA* **33**, pp107-109.

Cooper, T. P., (1988), Observations of Ophiuchid Meteor Activity during the 1988 Encounter, *MNASSA* **47,** pp147-152.

Cooper, T. P., (1994), Comet Shoemaker-Levy 9 collision with Jupiter, Research report 186/94 (14), Department of Mathematics, Applied Mathematics and Astronomy, University of South Africa.

Cooper, T. P., (1998), The Comet Hale-Bopp Album, archived document, Astronomical Society of Southern Africa.

Cooper, T. P., (2007), The Brightness Behaviour of Comet C/2006 P1 McNaught, *MNASSA* **66**, pp224-229.

Cooper, T. P., (2021a), The super-bolide of June 2, 2018 and meteorites from asteroid 2018 LA, *MNASSA* **80**, pp77-103.

Cooper, T. P., (2021b), The September upsilon Taurid meteor shower and possible previous detections, *eMeteorNews***, 6**, pp255-261.

Cooper, T. P. and Coronaios, K., (2022), Observations and images of Comet C/2021 A1 (Leonard), *MNASSA* **81**, pp30-56.

Jenniskens, P., (2006) in *Meteor Showers and their Parent Comets*, Cambridge University Press, ISBN-13 978-0-521-85349-1.

Jenniskens P., Gabadirwe M., Yin Q-Z, Proyer A., Moses O., Kohout T., Franchi F, Gibson R. L., Kowalski R., Christensen E. J., Gibbs A. R., Heinze A., Denneau L., Farnocchia D., Chodas P., Gray W., Micheli M., Moskovtiz N., Onken C. A., Wolf C., Devillepoix H. A. R., Ye Q-Z., Robertson D. K., Brown P., Lyytinen E., Moilanen J., Albers J., Cooper T. P., Assink J., Evers L., Lahtinen P., Seitshiro L., Laubenstein M., Wantlo N., Moleje P., Maritinkole J., Suhonen H., Zolensky M., Ashwal L., Hiroi T., Sears D. W., Sehlke A., Maturilli A., Sanborn M. E., Huyskens M. H., Dey S., Ziegler K., Busemann H., Riebe M., Meier M. M., Welten K. C., Caffee M. W., Zhou Q., Li Q-L., Li X-H., Liu Y., Tang G-Q., McLain H. L., Dworkin J. P., Glavin D. P., Schmitt-Kopplin P., Sabbah H., Joblin C., Granvik M., Mosarwa B., and Botepe K., (2021a) The impact and recovery of asteroid 2018 LA, *Meteoritics & Planetary Science* 56, 844-893, online version, doi: 10.1111/maps.13653.

Jenniskens, P., Heathcote, S., Jehin, E., Abbott, T., Towner, M., Hanke, T., Cooney, W., Cooper, T. and Lauretta,D., (2021b), A second Arid shower outburst in 2021, *eMeteorNews,* **7**, pp534-535.

Kay, J. and Streicher, M., (2008), *The Bennett Catalogue*, published by the Webb Deep Sky Society, ISBN 0-904824-08-X.

Kleyn, S., (2002), A F I Forbes of Hermanus, *MNASSA* **61**, pp189-193.

Kronk, G.W., Meyer, M. and Seargent, D.A.J., (1999), Cometography: Volume 5, 1960-1982: A Catalog of Comets, Cambridge University Press, 1999.

McIntyre, D.G., (1949) *Comets in old Cape records*, Cape Times Limited, published 1 Jan. 1949.

Moore, P., (1972), *The amateur in astronomy, in The Starlit Sky ’72*, a series of talks broadcast in the English Service of the South African Broadcasting Corporation during 1972.

Orchiston, W., (2003), J. F. Skjellerup: A forgotten name in South African cometary astronomy, *MNASSA* **62**, p72.

Ridley, H. B., (1962), The Phoenicid meteor shower of 1956 December 5, *JBAA*, 72, p266.

Smits, P. (1960), Presidential Address, *MNASSA*, **19**, pp79-93.

Venter, S. C., (1957), The Great Meteor Shower of 1956 December 5*, MNASSA*, **15**, p6.

Vermeulen, D. J., (2006), *Living Amongst the Stars at the Johannesburg Observatory*, Published by Chris van Rensburg Publications (Pty) Limited.

Appendix, Directors and timeline

William Reid
Director Comet Section 1922-1928; ASSA President 1925/6.

Donald G McIntyre
Director Meteor Section 1922-1926; ASSA President 1933/4.

Alexander F I Forbes
Director Comet Section 1929-1944; ASSA President 1942/3.

Ernest Leonard Johnson
Director Comet Section 1948-?

Stephanus Christiaan Venter
Director Meteor Section 1946-1958, Director Comet and Meteor Section 1962-1967, ASSA President 1956/7.

John Caister (Jack) Bennett
Director Comet and Meteor Section 1968-1985; ASSA President 1968/9.

Jose da Silva Campos
Director Comet and Meteor Section 1985-1992; ASSA President 1990/1.

Timothy (Tim) Cooper

Director Comet and Meteor Section 1993-2009; Director Comet, Asteroid and Meteor Section 2009-2013, and 2022 to date; ASSA President 2002/3.

ASSA AGM

This was a Hybrid meeting, held on 22 August, 2022 It was well attended and a full report will be presented in the next issue of *MNASSA.*

In the tables below are the details of the up-dated members of Council and all the Appointees for the period 2022/23

Role	Council Members 2022/23
President	Dr Daniel Cunnama
Vice President (Outgoing President)	Chris Stewart
Vice President (Incoming President)	Dr Pierre de Villiers
Treasurer	AJ Nel
Membership Secretary	Eddy Nijeboer
Secretary	Lerika Cross
Council Member	Case Rijsdijk
Council Member	Dr Ian Glass
Bloemfontein Representative	Thinus van der Merwe
Cape Chair	Christian Hettlage
Durban Chair	Amith Rajpal
Garden Route Chair	Case Rijsdijk
Johannesburg Chair	Carmel Ives
Pretoria Chair	Johan Smit
Hermanus Chair	Derek Duckitt

Role reporting into Council	Appointees
Convener of Scholarships	Dr Claire Flanagan
Communications Coordinator	Dr Sally MacFarlane
Observing Director	Angus Burns
Webmaster	John Gill

Web Manager: SAAO Liaison for Website	Dr Christian Hettlage
ASSA Archivist	Chris de Coning
Social Media Liaisons	Allen Versfeld (Twitter) Martin Heigan (Flickr) Sally MacFarlane (Youtube) Kos Coronaios (ASSA FB Admin) Chris Stewart (Mail groups)

Special Interest Groups	Directors
Dark Sky	Dr Daniel Cunnama
Observing	Angus Burns
Double and Variable Stars	Dave Blane
Photometry, Spectroscopy	Dave Blane (Caretaker role)
Cosmology and Astrophysics	Bruce Dickson
ASSA History	Chris de Coning
Astrophotography	Martin Heigan
Instrumentation (including ATM)	Chris Stewart
Comet, Asteroid and Meteor Section	Tim Cooper

Scholarships Committee	
Dr Claire Flanagan	Scholarship Convenor
Dr Ian Glass	Retired Professional Astronomer
Sivuyile Manxoyi	EUNAWE, SAAO outreach
Maciej Soltynski	Previous Scholarship Convenor
Dr Vanessa McBride	OAD, SAAO, UCT

Eight Years' Observations of Asynchronous Orbital Frequencies of the Redback Millisecond Pulsar PSR J1723-2837.

André van Staden (Overberg, South Africa)
andre@etiming.co.za

Abstract: I report here on extended photometric observations of the companion of a millisecond pulsar (MSP), PSR J1723-2837. The new eight years data, inclusive of Kepler K2 photometry data, confirmed our initial reports on modulated light curve signals that were not synchronized to the orbital period (van Staden & Antoniadis 2016).

The extended campaign now allowed for accurate tracking of asynchronous frequencies over time and identification of new signals. From my data it was possible to produce isolated light curves of these signals that had the properties expected from star spots. The identified spots showed lifetimes in excess of 5 years.

From the data presented, I have calculated the most extreme differential rotation of $\Delta\Omega/\Omega \approx -0.0055$, rotating faster than the orbital period while a rotation ratio of $\Delta\Omega/\Omega \approx 0.00079$ was observed, rotating slower than the orbital period.

1 INTRODUCTION

Redback and BW companion stars are believed to be tidally locked and their orbit circularized during a long evolution process (e.g. Hurley et al. 2002). However, van Staden & Antoniades (2016) showed that the companion star to PSR J1723-2837 showed modulation of the LC with asynchronous frequencies slightly above the orbital frequency, Ω_{orb} that we interpreted as spots rotating at a velocity in excess of Ω_{orb}. Since then, similar frequencies for PSR J1723-2837 were confirmed for by Novarino (2021) from analyzing Kepler K2 data and again confirmed in this report.

PSR J1723-2837, is a redback MSP with a 15.5 magnitude low mass companion star in a 14.8 hr orbit (Crawford, et al., 2013). This was to date the only MSP companion that showed asynchronous rotation and was therefore considered important for further study. Interestingly, PSR J1723-2837 also had a very large orbital period 1st derivative, $\dot{P}_b$ = −3.50(12) ×10^{-9} (Crawford, et al., 2013, Novarino et el. 2021). Orbital period variations of similar MSPs were commonly described in terms of the Applegate mechanism (Applegate 1992, Applegate & Shaham 1994) that required a magnetic active secondary. (see for example: Pletsch & Clark 2015; Clark et al. 2021 and Lazaridis et al. 2011).

The often seen irregular and asymmetric optical light curves in other redback MSPs were most likely also a consequence of star spots but were difficult to confirm due to generally limited coverage during (short) observation campaigns. Multiple spots (as we will see here) made detection even harder and I reported also on the associated problems due to observation spans that were too short..

The photometry of the companion star to PSR J1723-2837 is reported as follows: an account of spectral activity covering the eight years observation in section 4; the average brightness over eight years in section 5; a check for orbital period stability in section 6.1 (as a marker for asynchronous frequencies); a detailed analyses of asynchronous frequencies in sections 6.2 to 6.4. The identification of spots and the propagation of spots is illustrated with phase diagrams in section 7.

2 OBSERVATIONS AND PHOTOMETRIC REDUCTION

2.1 Overberg

The companion to PSR J1723−2837 was observed from 2014 to 2021 from Overberg, South Africa. The location of the observatory allows for continuous monitoring of the target for up to 9 hrs per night during winter, or 60% of the orbital period. All observations were conducted with a 30cm Cassegrain telescope and a commercial SBIG ST9e CCD camera cooled to -15°C, with 20µm^2 pixels arranged in a 512 × 512 grid.

Guiding corrections were performed with the integrated tracking CCD at 1 sec intervals, always using the same star. The images were calibrated using standard dark and sky-flat frames acquired sporadically throughout the campaign.

More than 11 000 images were collected over 200 nights (hereafter referred to as datasets), with exposure times of 300 seconds, except for 2015 when exposure times were 600 seconds. The images were reduced, based on visual inspection followed by a software routine that rejects images with large FWHM mainly caused by defocusing as a result of temperature fluctuations during the night, rapid sky background changes caused by high clouds and large standard error estimates by C-Munnipack, bringing the final images for this report to 8 665.

The magnitudes reported are based on differential ensemble type aperture photometry, computed with C-Munipack/Muniwin v. 2.2.29 (http://c-munipack.sourceforge.net/), a public photometry program. Fluxes were measured inside an aperture enclosing two times the FWHM of the local PSF, and the sky was extracted from a surrounding region up to five times the FWHM. The C-Munipack package uses the Robust Mean Algorithm based on a re-descending Ψ type M-estimator for calculating the sky background. Finally, neighboring photometric samples, obtained consecutively were averaged and the timing was compensated accordingly, thereby improving the S/N ratio to roughly the equivalent of 600 second integration time exposures. RMS values for a close-by star were computed for each dataset producing a mean rms for all sets of ≈2.7 mmag.

Time stamps were derived from PC time, which was synchronized to an international time server and checked regularly against a GPS master clock. All measurements were referred to Heliocentric times derived from the center of exposures.

2.1 Kepler Mission Data

PSR J1723-2837 was observed during campaign 11 of the Kepler K2 mission. Part of the motivation for the campaign was program “GO11901”, with title, “The Transitional Millisecond Pulsar PSR J1723-2837” with *John Antoniadis* as Principal Investigator (https://keplergo.github.io/KeplerScienceWebsite/k2-approved-programs.html) . The data may be obtained by following the links provided or from the MAST archive at https://archive.stsci.edu/k2/data_search/search.php?action=Search&ktc_investigation_id=GO11901. A helpful tutorial may be found at https://avanderburg.github.io/tutorial/tutorial3.html.

Campaign 11 was operationally separated into two segments as a result of an error in the initial roll-angle used to minimize solar torque on the spacecraft (https://keplergo.github.io/KeplerScienceWebsite/k2-data-release-notes.html#k2-campaign-11). This resulted in a short break in the data and an offset between the sets that was compensated for in my analysis reported here. The short cadence, datasets KTWO236020326-C111 and KTWO236020326-C121 with photometric data every ≈58.8 seconds were acquiring for this report and had an observation span of approximately 70 days. The start and stop times were respectively 2016-09-24 to 2016-10-18 and 2016-10-21 to 2016-12-07.

The LC was normalized followed by a conversion from Kepler flux in electrons/sec to Kepler magnitudes (see for example: https://astrobase.readthedocs.io/en/latest/astrobase.astrokep.html).

3 FREQUENCY ANALYSIS

Fourier analysis was performed on the LC data of J1723-2837 using Period04 v. 1.2.0 code (Lenz & Breger 2004, 2005, Ponman, 1981), a program especially dedicated to the statistical analysis of large astronomical time series containing gaps. Additionally, my own code in Matlab was use *ad hoc* as required.

The search for frequencies in Period04 works in an iterative way by first finding the highest peak as a significant signal with a Lomb–Scargle periodogram followed by a multi-period least-squares fit using the formula:

$$f(t) = Z + \sum_{i=1}^{\infty} \boldsymbol{A}_i \sin(2\pi(\Omega_i\, t + \phi_i)) \quad (1)$$

where $t = T_{observed} - T_{asc}$, $Z \approx 0$ a *zero-point* offset, $\boldsymbol{A}_i$ is the amplitude, Ω_i = frequency, ϕ_i = phase and *i* the range of functions.

The data were then pre-whitened with the derived fit for further analysis. In each iterative step, the solutions (f_i) were subtracted from the LC data and the residual was obtained to search for significant frequency in the next step. This algorithm was repeated until no significant frequency peaks were detected. In each step the alias frequencies associated with the sampling frequency of the signal were also removed, leaving a much cleaner spectrum for the next iteration (Aerts et al. 2010., Robert J., 2018., Sullivan D. J.,2019).

It may be noted that *the parameters of the functions had a strong correlation with each other that might lead to nonconvergence and quite large errors. Care had to be taken at each step, monitoring all parameter for radical changes*. In some instances, it was better to limit or decrease the number of iterating steps. Another technique was used when smaller signals were of importance, the first batch of frequencies being kept fixed (locked) at their known values while searching for smaller signals. In this report, I only focused on the two or three most significant signals.

4 AN EIGHT YEAR SPECTRAL HISTORY OF PSR J1723-2837

I searched for Fourier signals in my LC up to frequencies of 150 c/d. No significant signals above 6 c/d were detected. Figure 1 shows an eight year, pre-whitened spectral history of the companion to PSR J1723-2837 from 2014 to 2021, up to 6c/d. Only the signals resulted from the pre-whitening analyses were plotted in the figure: therefore the contamination of alias frequencies have been removed.

Evidently, PSR J1723-2837 could be characterized by three frequencies dominating the spectrum: the frequencies close to zero representing the long term change in magnitude; the frequency at double the orbital frequency, $2\Omega_{orb}$ = 3.24972359 c/d (indicated with a red dot-dashed marker in figure 1) representing ellipsoidal modulation and co-orbital frequencies that coincide with orbital rotation at a frequency, Ω_{orb} = 1.6248 c/d (red dashed marker) *that will be examined in the remainder of this report*.

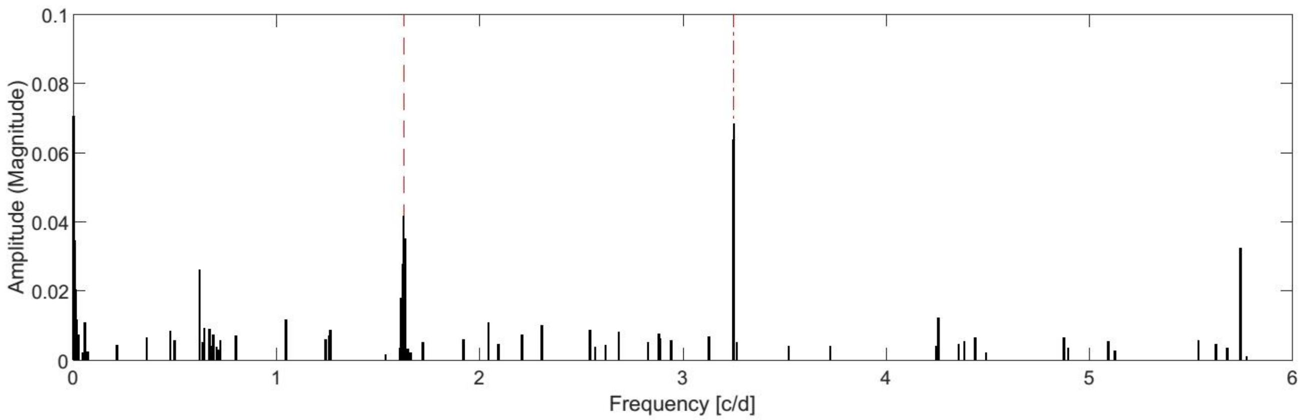


Fig 1. An eight-year, spectral representation up to 6 c/d of the companion star's LC of PSR J1723-2837. The dashed and dashed-dot lines were respectively indicators of the orbital frequency (1.624863075 c/d) and ellipsoidal frequency (3.24972615 c/d). Frequencies close to 0 c/d were related to magnitude changes over the eight-year span (see section 5).

5 LONG TERM AVERAGE PHOTOMETRIC FLUX CHANGE

Figure 2 shows the photometric LC of the companion to PSR J1723-2837 from 2014 to 2021. From the extended eight year data, we saw a very firm dip in average magnitude over time. In order to estimate the true change in average magnitude, the LC was approximated with 20 sine functions, compensating for all secular variation (e.g. spots on the surface of the star, etc.) that may have altered the average magnitude change. The frequencies close to zero were then regarded as the long term change in magnitude with the four most significant low frequency signals listed in table 1. Function #1 was by far the most prominent signal and was over-plotted on the LC in figure 2.

Considering that this was a reasonable fit and covered almost one cycle of the LC, I took the companion star to be potentially a variable with a period, $\mathbf{P}_{\Delta m}$ ≈ 10.068 years and a change in brightness of Δm ≈ 0.124 mag.

TABLE 1

Function	Frequency [c/d]	Period [d]	Amplitude	Phase
1	0.00027211	3.6749×10^3	0.06202	0.435655
2	0.00151498	6.6007×10^2	0.01531	0.473612
3	0.00371443	2.692×10^2	0.01039	0.444848
4	0.00093627	1.068×10^2	0.00449	0.335875

Table 1. The most prominent Fourier signals in the low frequency band of the modeled LC.

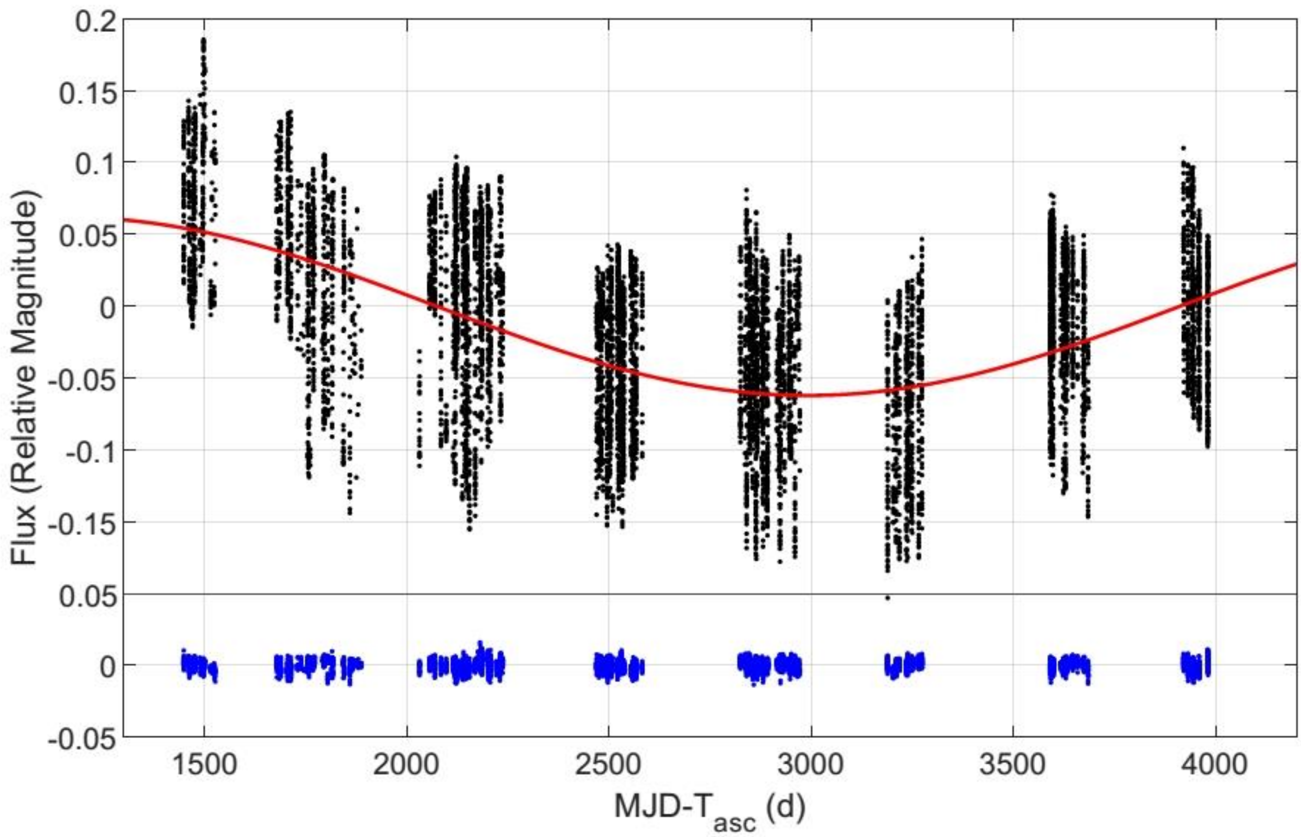


Fig2. Time series photometry of PSR J1723-2837 over an 8-year span shown in black. The average change in magnitude was shown with the red curve, representing a best fitted, least square sine function with properties listed in Table 1, Function #1. A nearby comparison star was continuously monitored during the campaign and was shown in blue at the bottom at the same magnitude scale.

6 CO-ORBITAL FREQUENCIES

6.1 Checking orbital period stability (Ellipsoidal Modulation)

Asynchronous frequencies could be defined as the amount of deviation from a frequency that was equal to the inverse of the orbital period. The orbital period, P_b =0.615436473(8) was determined from the radio timing ephemeris (Crawford,et al. 2013) but was checked here to see if the period was still consistent during the campaign. For a reference, the ellipsoidal signal (see section 4 and figure 1) was used as a marker since the signal was modulated by the orbital (period) rotation. Comparing my orbital period measurements (see Table 2) during the campaign showed an insignificant change of $\Delta P = -4.84 \times 10^{-7}$ by comparing to P_b. Additionally, the Kepler K2 data was checked with no significant change either.

TABLE 2

	Mean Time MJD	Ellipsoidal Frequency [d^{-1}]	Frequency Sigma	Orbital Period P_{meas}[d]	ΔP [d] = (P_b - P_{meas})[(e)]
Author[(a)]	58121.5926	3.24972359[(c)]	5.9x10^{-7}	0.615 436 9(1) [(d)]	-4.84x10^{-7}
Kepler[(b)]	57693.2296	3.24972878 [(c)]	3.7x10^{-6}	0.615 435 9(7)[(d)]	5.73x10^{-7}

Observation from Author: from 03-Aug-2014 to 11-Jul-2021
Observation from K2 Kepler mission: from 21-Oct-2016 to 07-Dec-2016.
Frequencies determined with *Period04 (see sections 3 & 4)*
Orbital Period = 2/ (Ellip freq)
P_b =0.615436473(8), derived from radio timing ephemeris, Crawford, et al. (2013)

Table 2. Ellipsoidal frequency measurements

6.2 Identification of asynchronous frequencies.

In 2016 we showed that the companion star to PSR J1723-2837 showed signs of asynchronous rotation (van Staden & Antoniades, 2016). Since then, similar frequencies were confirmed by Novarino (2021) from Kepler K2 data (see also section 3.2). Moreover, Novarino also pointed out significant Fourier signals marginally below Ω_{orb} that were confirmed in this publication. I define here asynchronous frequencies larger than orbital frequency as Ω^+ and similarly frequencies below the orbital frequency as Ω^- .

6.3 The problem with short data spans

In the next section it was shown that at least two asynchronous frequencies, closely spaced, were present most of the times. This and other factors make accurate derivation of the frequencies difficult for short data spans. From practical trials it was noticed that the strong correlation of parameters between functions as mentioned in section 3 ("Frequency Analyses") was more significant in the short data spans.

In general, *it was found that extending the data over longer spans, for example two or three years combined, delivered more persistent frequencies* as we shall see in next sections.

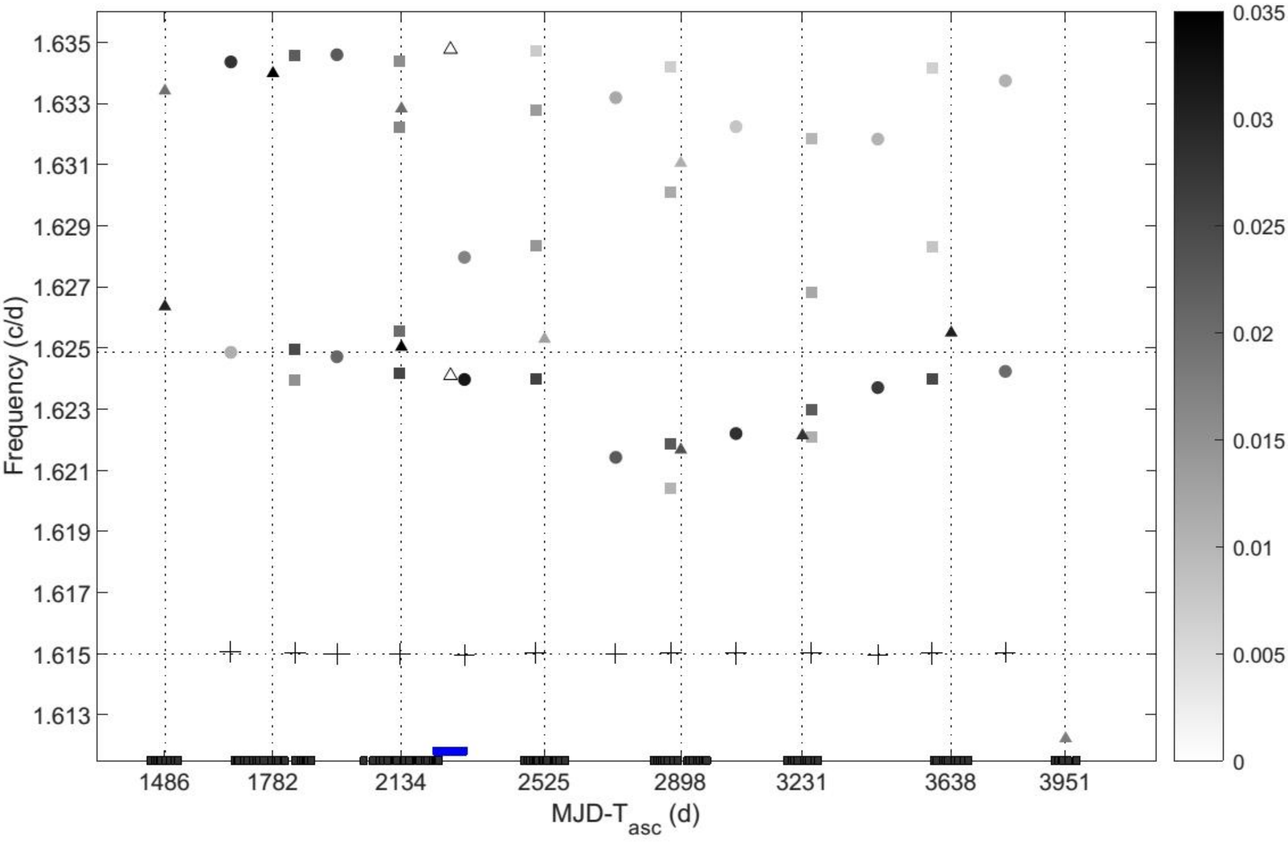
Moreover, the Kepler data for instance produced similar frequencies to my data but not the exact frequencies when compared to my combined 2-yr and 3-yr sets (shown in the next section). However, a trial was made where I entered the frequency value of the sine function for the first asynchronous signal to the pre-whitening algorithm (as expected from my 2-yr data and covering the same time) instead of the frequency suggestion by the FFT. Interestingly, the algorithm then calculated the next asynchronous frequency that matched the expected 2nd frequency value. In a final step of the process, (with 10 sine function modeling the LC) all the frequencies were set again as free parameters and a best simultaneous solution was again determined. The two significant asynchronous frequencies were then confirmed to *remain steady* and matched my frequencies. The Kepler data span was ~70 days and do showed subtle frequency ambiguities in short data spans.

On the negative side it should be noted that the number of alias frequencies also increases significantly with the yearly data gaps. Furthermore, signals with a varing frequency may manifest in the spectrum as multiple frequencies. This is well known for frequency modulated signals (FM) that produce side band in the frequency spectrum. Also, longer data spans will increase the probability that the frequency might drift during that period, as we will see in the coming sections. Nevertheless, the data presented in the next section included yearly, two yearly and three yearly sets for evaluation.

6.4 An eight year glance and evolution of asynchronous frequencies

Figure 3 showed co-orbital, asynchronous frequencies near Ω_{orb} with signal intensities, observed and measured from 2014 to 2021. In addition to yearly frequency measurements, data were combined and measured over two and three year spans which may be identified by the marker-legend below the plot.

Evidently the asynchronous frequencies were scattered while the ellipsoidal frequency (Offsetted here for display purposes and indicated with "+" markers) was consistently stable.



▲ = Yearly	Δ= Kepler	● = 2 Years	■ = 3 Years	+ = 2 & 3 Yrs (Ellipsoid)

Fig 3. LC Frequencies measured from 2014 to 2021. The square markers at the bottom were actual observation dates. The vertical dotted lines were the center dates for the yearly observations and coincided approximately with June/July/August for each year. The top horizontal dotted line indicated the orbital frequency, Ω_{orb}. Reported frequencies were based on the data spans as indicated by the marker legend. The intensity of the markers was related to the amplitude of the signal and may be matched to the right side bar. The crosses ("+") were ellipsoidal frequencies (measured over 2-Year and 3-Year data spans) but offsetted and plotted here at ~1.615 (to scale) in order to illustrate the orbital stability relative to the asynchronous frequencies.

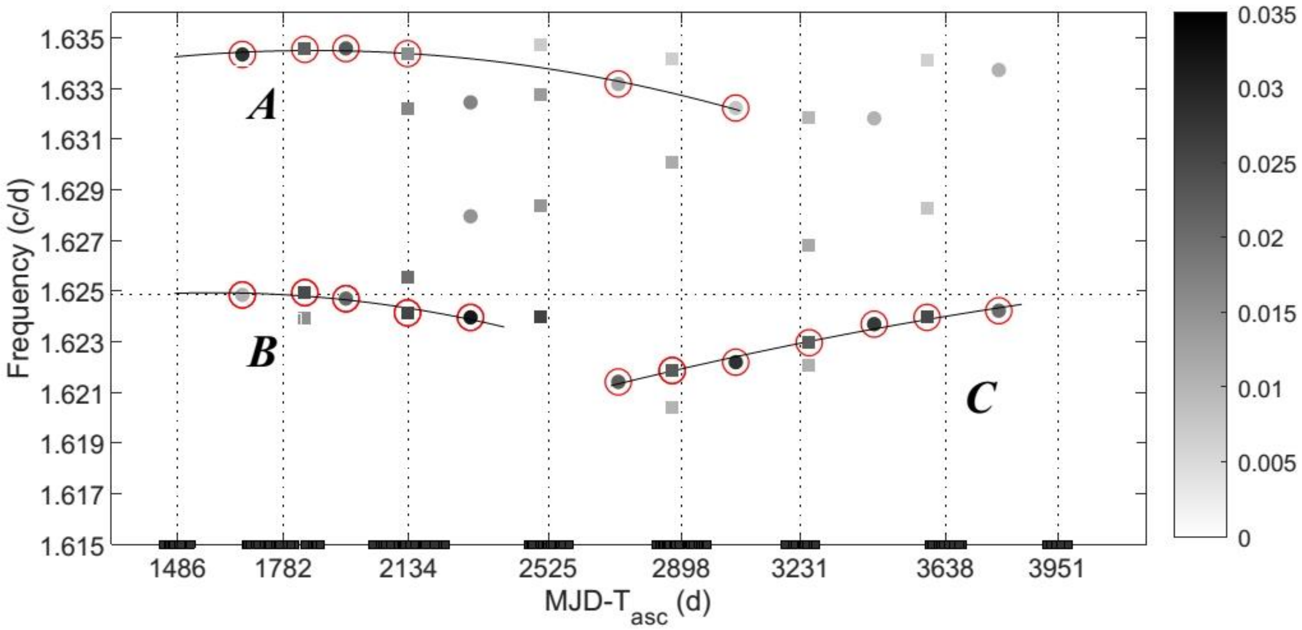
From the scattered frequency plot, it could be seen that there were frequencies (Ω^+) larger than orbital frequency and frequencies (Ω^-) below the orbital frequency. On closer inspection I could identify three frequency groups of prevalent signals, which drifted over time. For clarification, I reproduced the two and three year span frequencies in figure 4 and marked the groups as **A**, **B** and **C** and I encircled (in red) frequencies that seems to be elementary to the groups. From the selected frequencies, I computed least squares fitted functions for each group. Groups **A** & **B** were approximated with quadratic functions while the **C**-group had insignificant residue between 1st and 2nd order polynomials and settled for a linear function. The related curves from the functions were over plotted in figure 4 and had the following equations:

$\Omega_A^+(t)$ = -1.661672 x 10^{-9} t^2 + 6.199749158 x 10^{-6} t + 1.628728949 (2)
$\Omega_B^-(t)$ = -1.665578 x $10^{-9}t^2$ + 5.001233001 x 10^{-6} t + 1.621238897 (3)
$\Omega_C^-(t)$ = 2.759528481 x 10^{-6} t + 1.613919610 (4)

Where: t was related to MJD- $\boldsymbol{T}_{asc}$.

Since related phase information was required in the next section, the three equations were additionally integrated and produced the following equations:

$\phi_A(t) = \int \boldsymbol{\Omega}_A^+ \, dt$ = -5.5389066 x10^{-10} t^3 + 3.0998745790 x $10^{-6}t^2$ +1.628728949 t + C (5)
$\phi_B(t) = \int \boldsymbol{\Omega}_B^- \, dt$ = -5.5519266 x10^{-10} t^3 + 2.5006165005 x $10^{-6}t^2$ +1.621238897 t + C (6)
$\phi_C(t) = \int \boldsymbol{\Omega}_C^- \, dt$ = 1.3797642405 x $10^{-6} \cdot t^2$ + 1.613919610 $\cdot\, t$ + C (7)



● = 2 Years	■ = 3 Years

Figure 4. A reproduction of figure 3 with only the two and three year span frequencies. Encircled in red were frequencies that seem to be elementary to the two groups. The fitted curves were computed from the frequencies encircled and was explained earlier.

7 IDENTIFICATION OF SPOTS AND THEIR LIFETIMES

7.1 Isolating the spots

In this section, the photometric LCs of the companion star were reduced to subsets containing only the signals related to the frequencies in the groups (A, B &C). The phase and amplitude behaviour was then investigated with a series of phase diagrams (or folded LCs).

The focus here was again primarily on the 2-yr data spans. Two phase LC's were produced for each 2-yr span. The process involved is summarized in table 3 ("Data flow") for one excursion of a single 2-yr LC.

Table 3: Data Flow

Original **LC** from Combined 2 yr span	→	Modeled with 10 sine functions (equation 1)	→	**LC** Data 1st Year	→	Y_xObserved (t) $Y_{x\ \mathrm{Computed}}$ (t)	→	Phase **LC**	→	Figure a
				LC Data 2nd Year	→	Y_xObserved (t) $Y_{x\ \mathrm{Computed}}$ (t)	→	Phase **LC**	→	Figure b

The isolated LC signals, $\boldsymbol{Y_x}_{\ \mathrm{Observed}}$ (t) was in principal the residue of the original LC after subtraction of all the pre-whitening sine functions (about 9) excluding the designated signal, associated with that dataset from the original LC. This was realized with the following equations:

$$\boldsymbol{Y_x}_{\ \mathrm{Observed}}(t) = (\ LC(t) - Z\ ) - (\ \textstyle\sum_{i=1}^{x-1} \boldsymbol{y}_i + \sum_{i=x+1}^{n} \boldsymbol{y}_i\ ) \text{ and}$$
$$\boldsymbol{Y_x}_{\ \mathrm{Computed}}(t) = \boldsymbol{y_x}$$

Where:

$\boldsymbol{x}$ referred to the function number $\boldsymbol{i}$ of the signal to be isolated,
$\boldsymbol{i}$ is the range of functions, counting from 1 to n,
Z ≈ 0 a *zero-point* offset (see equation 1),
$\boldsymbol{y}_i = \boldsymbol{A}_i \sin(2\pi\, \phi_i + 2\pi\, \Omega_i\, t)$,
$\boldsymbol{A}_i$ is the amplitude, Ω_i is the frequency, ϕ_i is the phase from the pre-whitening algorithm (equation 1) and
t was the timing of observations of the LC where $t = MJD - T_{asc}$

For the phase diagrams, phases were calculated with the derived equations, 5,6 &7 (opposed to the best analytical frequencies) that included the frequency drifting (note that the constants, C could be ignored). Therefore, a signal propagating with that (drifting) frequency should remain coherent in the phase diagrams independently of large time gaps in-between data sets.

Two phase LCs were calculated for each 2-yr span, one for the 1st year and and one for the 2nd year (see "Data Flow" illustration). This allowed for spotting yearly changes in the phases (or general wave shape) versus a 2 year period.

The phase diagrams (figures 5 to 18) were sequentially sorted in the previously defined groups **A**, **B** & **C** in order to easily compare phases between plots. (Note that the phase-axis of the phase diagram, was no longer related to the orbital position since the folding period ≠ P_b). Information for each figure was listed in tables 4, 5 & 6. For each phase diagram, I identified the signal with a spot ID, starting with group A. The first spot was then simply A1 followed by A2, etc. An asterisk behind the ID, e.g. A1(*), showed that the phase may still be part of the previous (A1) spot but is definitely in the process of changing phase.

Table 4: Frequency group **A**

Figure	*Data set*	*Function nr. (i)*	*Function Freq Ω_i (c/d)*	*Function Amplitude A_i*	*Folding Phase Equation*	*1st Year*	*Spot ID*	*2nd Year*	*Spot ID*
5. a,b	2014-2015	2	1.6342	0.0279	5	2014	**A1**	2015	**A1**
6. a,b	2015-2016	3	1.6346	0.0226	5	2015	**A1**	2016	**A1**
7.	Kepler (2016)	2	1.6348	0.0187	5	2016	**A1**		
8. a,b	2016-2017	4	1.6325	0.0174	5	2016	**A1 (*)**	2017	**A2**
9. a,b	2017-2018	4	1.6332	0.0118	5	2017	**A2**	2018	**A2**
10. a,b	2018-2019	3	1.6322	0.0080	5	2018	**A2**	2019	**A2**

Table 5: Frequency group **B**

Figure	*Data set*	*Function nr*	*Function Freq (c/d)*	*Function Amplitude*	*Phase Equation*	*1st Year*	*Spot ID*	*2nd Year*	*Spot ID*
11. a,b	2014-2015	6	1.6248	0.010576	6	2014	**B1**	2015	**B1**
12. a,b	2015-2016	4	1.6253	0.0229	6	2015	**B1 (*)**	2016	**B2**
13	Kepler (2016)	2	1.6241	0.0206	6	2016	**B2**		
14. a,b	2016-2017	2	1.6239	0.03044	6	2016	**B2**	2017	**B2**

Table 6: Frequency group **C**

Figure	*Data set*	*Function nr*	*Function Freq (c/d)*	*Function Amplitude*	*Phase Equation*	*1st Year*	*Spot ID*	*2nd Year*	*Spot ID*
15. a,b	2017-2018	2	1.6214	0.0225	7	2017	**C1**	2018	**C1**
16. a,b	2018-2019	2	1.6222	0.0283	7	2018	**C1**	2019	**C1**
17. a,b	2019-2020	4	1.6237	0.0271	7	2019	**C1**	2020	**C1**
18 a.b	2020-2021	2	1.6242	0.0204	7	2020	**C1**	2021	**C1**

7.2 The propagation of spots within groups

From the phase diagrams we saw instances where the signals within groups remained phase coherent (for up to 5 years, e.g. spot C1). This was remarkable since the effective folding of the phase diagrams was no longer related to a fixed period and proved to some extend the integrity of the phase equations (5-7) as well as the drifting of frequencies. Phase ambiguity (resulted from complete cycle slips) between years was unlikely as we expected then to see smearing out of signals on (smaller) yearly data. The coherency also confirmed spot lifetimes in excess of 5 years since the (beginning or end) of the spot lifetimes could have been outside my 8-year time span of observations.

Incidentally, the absence of the expected frequency for the A-Group, 2016-2017 (2-yr span) seemed puzzling at first glance (see figure 4). Curiously, two once-off “new” frequencies at ~1.632 and ~1.628 were seen. A possible explanation for this was a change in phase of the $\Omega_A^+(t)$ signal occurring in 2016 that manifest as “new” signals. (Of course the implications of FFT analysis of non-coherent signals is beyond the scope of this report). However I would also like to put this event in context wi th the next section (see “Flip-Flop”).

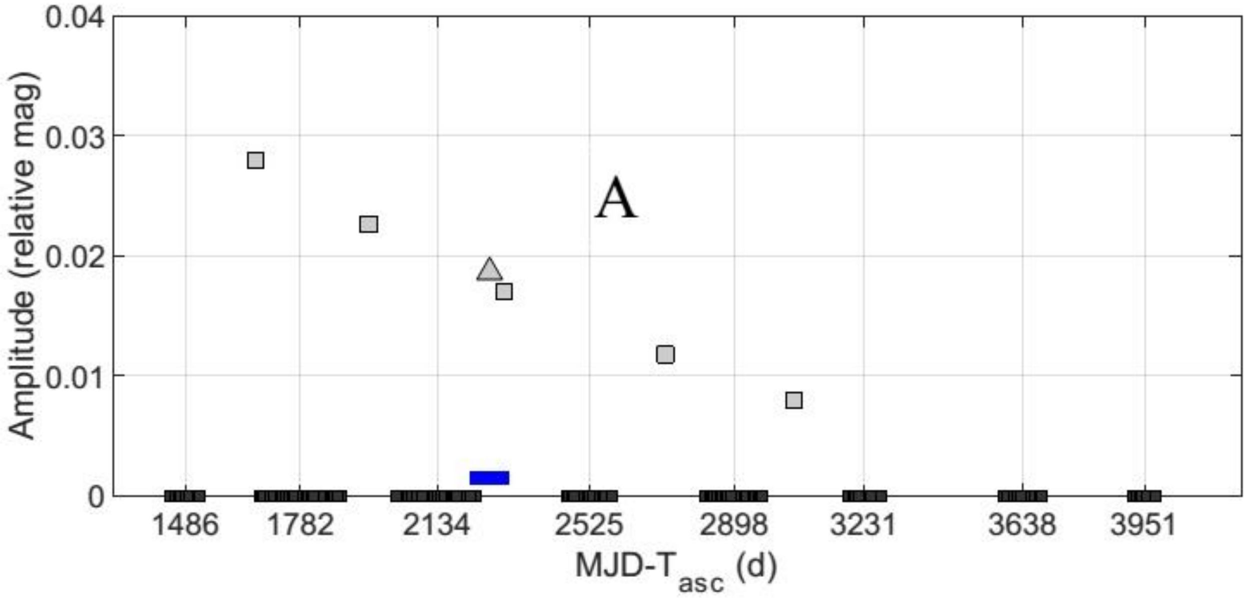
In summary, the A-Group produced a series of phase diagrams that may be interpreted as two (or one) spots that faded towards the end of a 5 year period. The phase diagram from the Kepler data also agrees nicely with the author’s data.

The B-Group showed a more transient behavior over a shorter period. This may be indicative of a more active region of multiple transient spots. Alternatively the function describing the frequency drift (equation 3) needs optimization. The phase diagram from the Kepler data again fits in accurately with the author’s data.

Group-C showed good quality, persistent in-phase, phase diagrams that were likely a single spot observed for at least a 5-yr period.

7.3 Spot Amplitudes

If the signals detected here were a result of star spots, then the amount of modulation of the LC observed will be related to physical parameters of the spots (e.g. size, temperature, etc.). In this report, I took the modulation that was described by the Amplitude ($\boldsymbol{A}_i$) of the functions produced by the pre-whitening algorithms at face value as a comparative measure. For example, if $\boldsymbol{A}$(t=2014) = $\boldsymbol{A}$(t=2015) the implication was a good probability that the physical parameters agree and the same spot was observed for both dates.



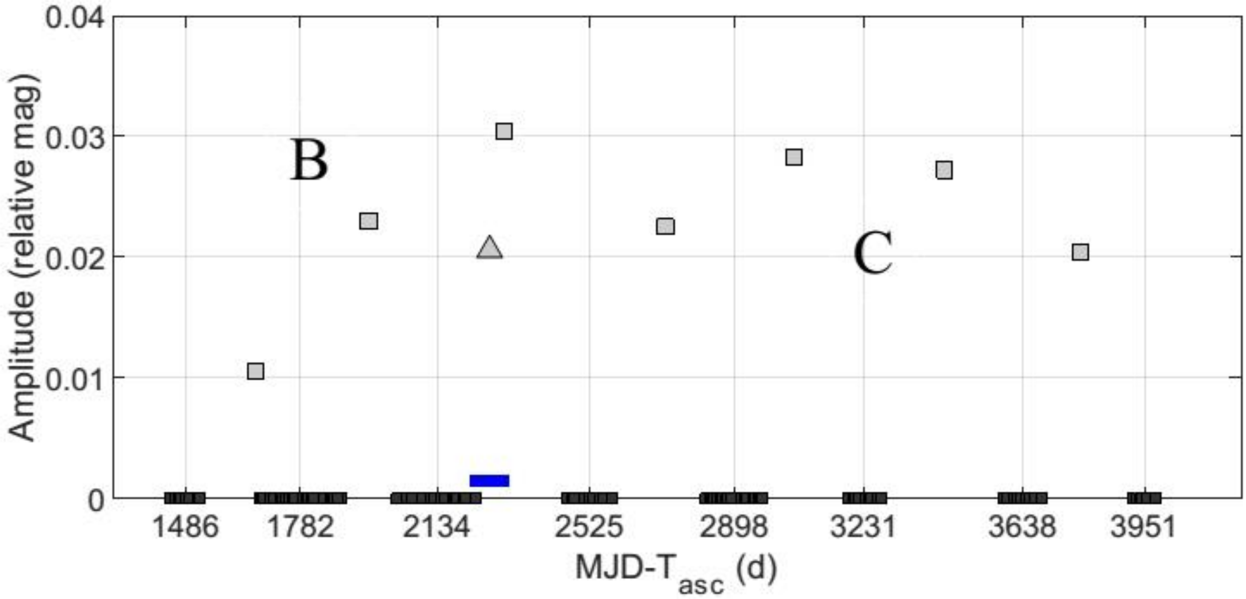


Fig 19. Amplitude evolution of the A-Group spots (Top) and B&C-Group spots (Bottom). The author's data was shown with squares and Kepler data with triangles.

The amplitudes ($\boldsymbol{A}_i$) for all spots were listed in tables 4 to 6 and were plotted in figure 19. Group-A showed a most remarkable, almost linear decrease of amplitude that seemed to be at face value a single spot dissipating over time. However, from the phase diagrams, it appeared as two spots. A possible explanation was that we witnessed a phase jump during 2016-2017 of ~0.4 (almost 180°) for the A-Group.

Phase jumps in longitudinal position are not an uncommon phenomenon and may be explained with the "Flip-flop" phenomenon, in which the main part of the spot activity changes 180° on the stellar surface. This was first discovered in the early 1990s on a single, very active, giant, FK Com (Jetsu et al. 1991, 1993). According to the calculations by Elstner & Korhonen (2005) the shift of the spots in a flip-flop event is 180° only in some cases, mainly for the stars with thin convective zones. In stars with thick convective zones they found a shift that is close to 90°.

Finally, amplitudes in Group-B showed an increase over a small period while the C-group fluctuated around a mean of ~0.025 magnitudes.

8 CONCLUSION

High density photometric data in the current campaign for the companion to PSR J1723-2837 stretched now over an eight year period, collectively yielding more than 11 000 images (300 seconds exposures each) during more than 200 nights. Since this was the only millisecond pulsar system to date that showed asynchronous rotation, the long span campaign by the author was considered of importance to the understanding of redbacks and the black widow class of millisecond pulsars. This campaign was also made possible by the relative bright companion of ~15.5 magnitude that was in range of a small telescope.

Photometry data from Kepler spacecraft K2 mission was also analyzed and of great importance, confirming observations by the author of similar signals but was in fact of too short span to provide a broader picture.

From my yearly data I was able to track the photometric average brightness of the companion star over eight years and could report here on the (first) long term magnitude change of a redback millisecond pulsar with a preliminary estimated variable period, $P_{\Delta m} \approx 10.068$ years.

Novarino, et al (2021) independently analyzing photometric Kepler data (2016), confirmed that they saw similar asynchronous frequency in the LC from PSR J1723-2837 to what we discovered earlier (van Staden & Antoniades, 2016). Moreover, Novarino (2021) also pointed the detection of Fourier signals marginally below Ω_{orb} that were also locally observed and reported here.

Roughly speaking, the A-Group had a mean frequencies of ~1.6338 c/d while the B&C Group combined had a mean of ~1.6235 c/d which may be due to two different latitudes rotating asynchronously with a mean differential rotation of $\Delta\Omega/\Omega = -0.0055$ and $\Delta\Omega/\Omega = 0.00079$ consecutively. With the longer campaign it was possible to track frequencies over time (in three groups) that showed drifting of the frequencies over time that could be described by simple equations. This was a surprising discovery and may be explained in term of migration of star spots and was in fact more compelling evidence of star spots in a differential rotating star, similar to our own sun. However a more in-depth study was required to evaluate various potential options for explaining the observations especially by comparing to other stars with spots.

Finally in this report it was shown that by isolating the spots from the LC, remarkable phase coherencies were observed by means of a series of yearly phase diagram. Spot lifetimes were estimated, ranging from 1 year to over 5 years.

9 REFERENCES

Applegate, J. H., 1992, *ApJ*, **385**, 621

Applegate, J. H., & Shaham, J., 1994, *ApJ*, **436**, 312

Aerts C., Christensen-Dalsgaard J., Kurtz D. W., 2010, Asteroseismology Springer.

Clark C J, Nieder L, Voisin G, 2021, "Einstein@Home discovery of the gamma-ray millisecond pulsar PSR J2039–5617 confirms its predicted redback nature", *MNRAS*, **502**, 915–934.

Crawford, F., Lyne, A. G., Stairs, I. H., et al., "*An Eclipsing Binary Radio Millisecond Pulsar*" 2013,ApJ, **776**, 20.

Elstner D., Korhonen (2005), "Flip-flop phenomenon: observations and theory", https://arxiv.org/abs/astro-ph/0501343v1.

Hurley Jarrod R, Christopher A. Tout, Onno R. Pols, 2002, "Evolution of binary stars and the effect of tides on binary populations", *MNRAS*, **329**, Pages 897–928.

Jetsu, L., Pelt, J., Tuominen, I., Nations, H.L.: 1991, in: The Sun and Cool Stars: activity, magnetism, dynamos, Tuominen I., Moss D., Rüdiger G. (eds.), Proc. IAU Coll. 130, Springer, Heidelberg, p. 381

Jetsu, L., Pelt, J., Tuominen, I.: 1994, *A&A* **278**, 449

Lazaridis K., et al., 2011, "Evidence for gravitational quadrupole moment variations in the companion of PSR J2051−0827", *MNRAS,* **414**, 3134–3144.

Lenz P., Breger M., 2004, "The A-Star Puzzle Vol. 224, Period04: A software package to extract multiple frequencies from real data." 786–790

Lenz P., Breger M., 2005, *Communications in Asteroseismology*, **146**, 53

Novarino M. L., Echeveste M., 2021, "Effect of tides on the orbital evolution of the redback system PSR 1723–2837 *MNRAS*, **508**, 3812–3819.

Pletsch, H.J., Clark C. J., 2015,"*Gamma-Ray Timing of Redback Psr J2339–0533: Hints For Gravitational Quadrupole Moment Changes*", *ApJ,* 807, 18

Ponman T, 1981, "The Analysis of periodicities in irregularly sample data" *MNRAS*, **196**, 583-596.

Robert J. Dukes Jr. and Saul J. Adelman, 2018, *PASP,* **130**, 044202

Sullivan Denis J., 2019, "Analysis of Pulsating White Dwarf Star Light Curves",DOI: 10.5772/ intechopen.86404'

Van Staden A D., 2016 PSR J1723-2837: "Intensive photometric study captured unique events". *MNASSA* **75** Nos 1 and 2

Van Staden A. D., Antoniadis J., 2016, "An Active, Asynchronous Companion To A Redback Millisecond Pulsar", *ApJ*, **833**, L12.

Phase Plots - GROUP A

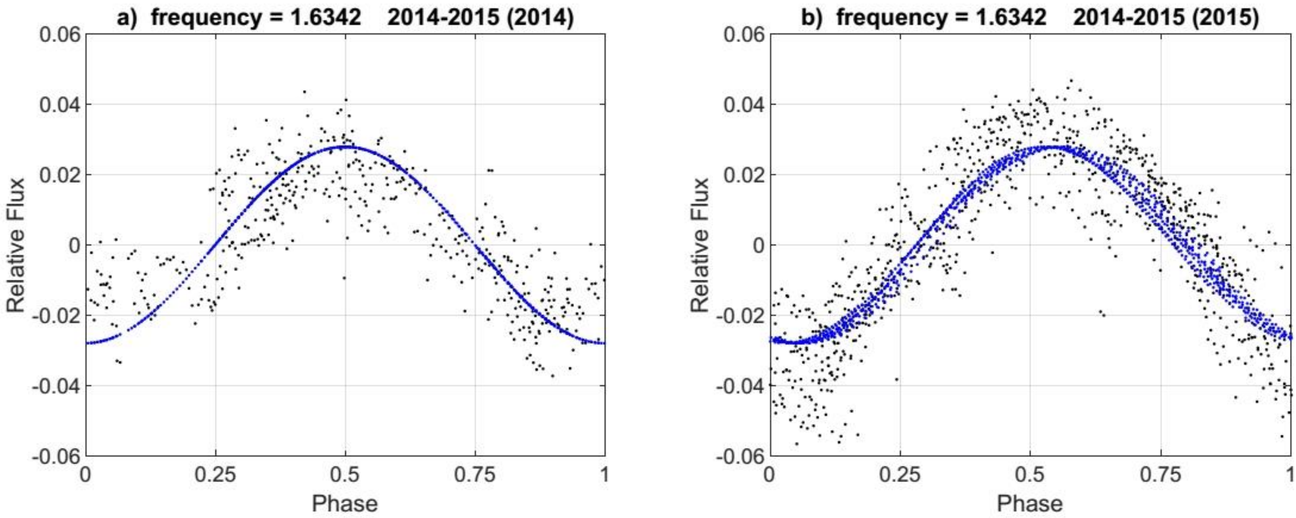


Fig 5. Phase plots for (a) 2014 and (b) 2015. See table 4 for details.

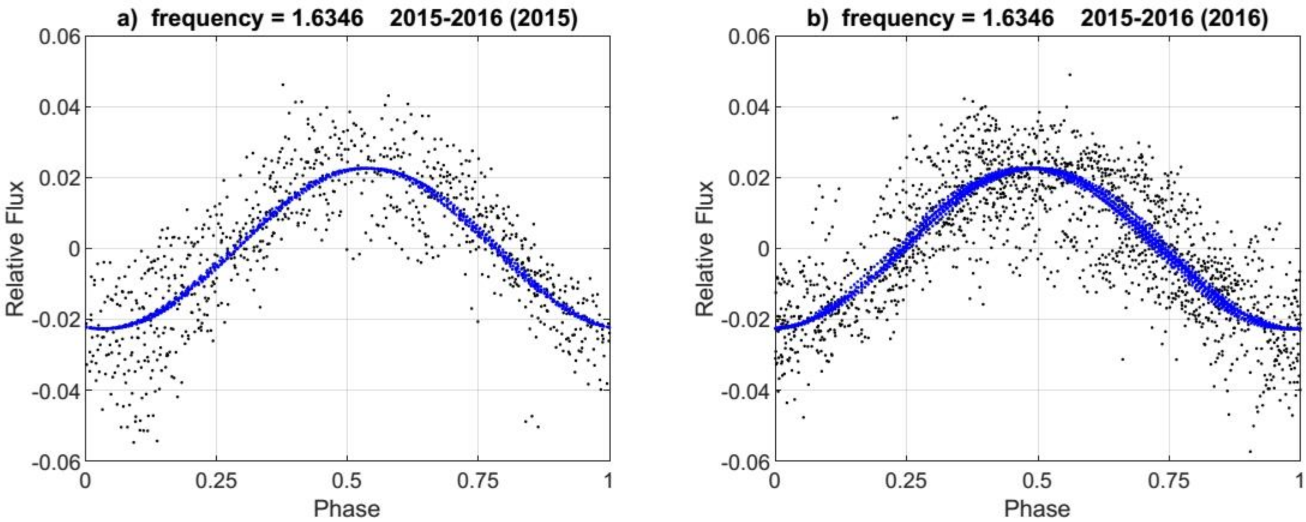


Fig 6. Phase plots for (a) 2015 and (b) 2016. See table 4 for details.

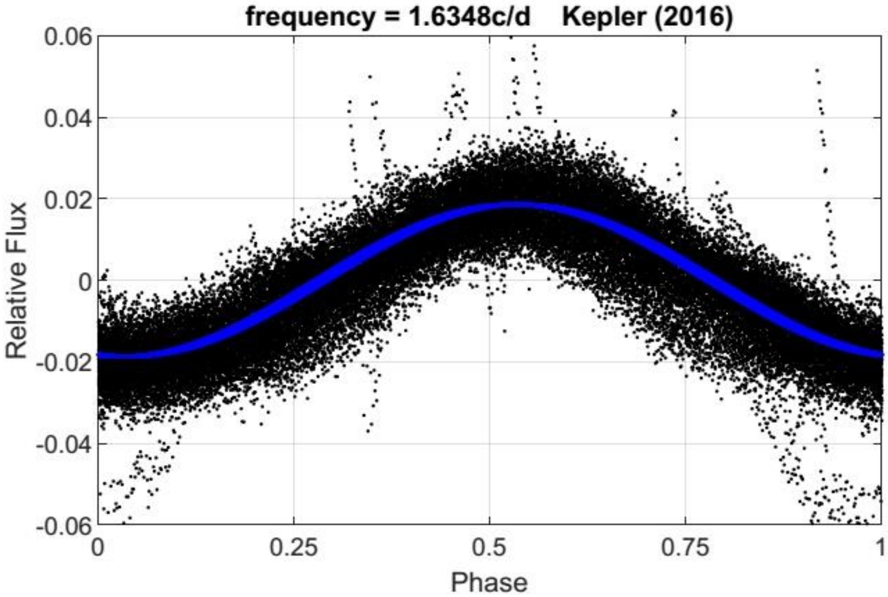


Fig 7. Kepler Phase plot for 2016. See table 4 for details.

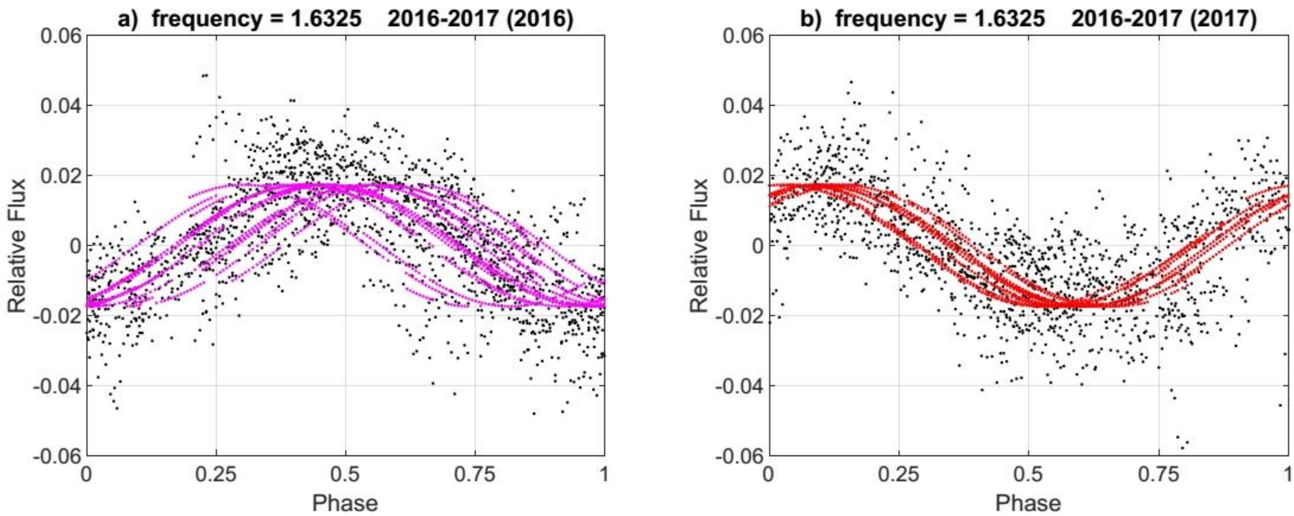


Figure 8. Phase plots for (a) 2016 and (b) 2017. See table 4 for details.

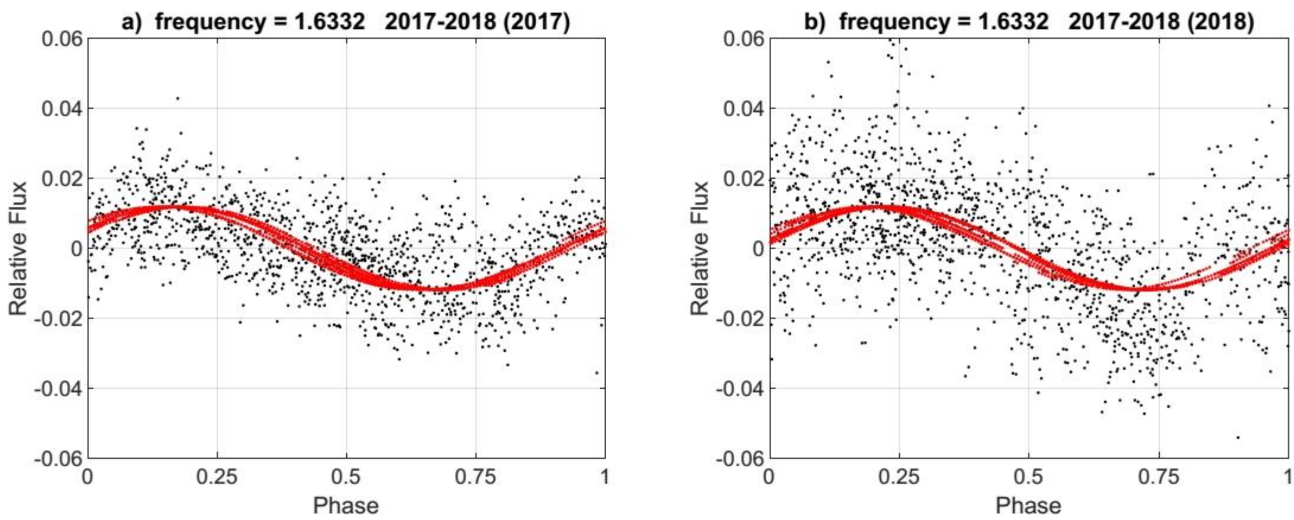


Fig 9. Phase plots for (a) 2017 and (b) 2018. See table 4 for details.

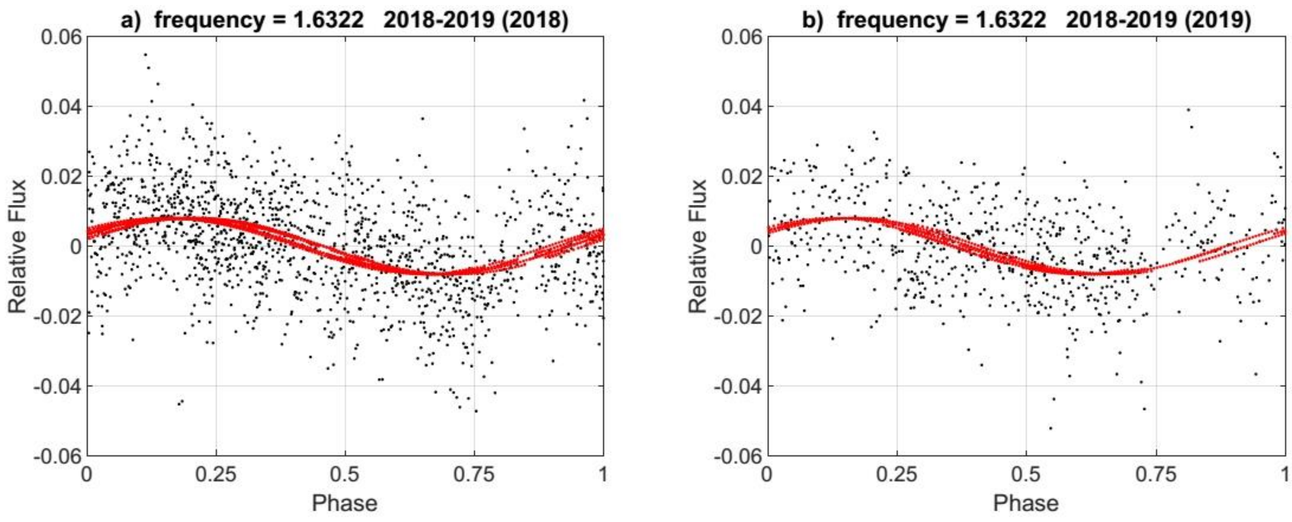


Figure 10. *Phase plots for (a) 2018 and (b) 2019. See table 4 for details.*

<u>Phase Plots - GROUP B</u>

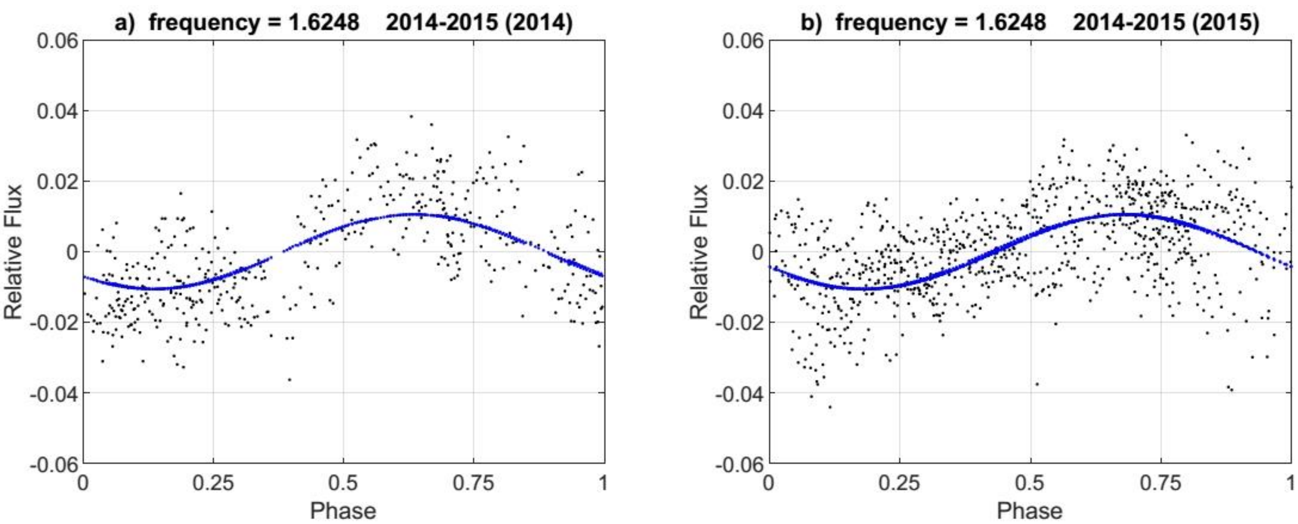


Fig 11. Phase plots for (a) 2014 and (b) 2015. See table 5 for details.

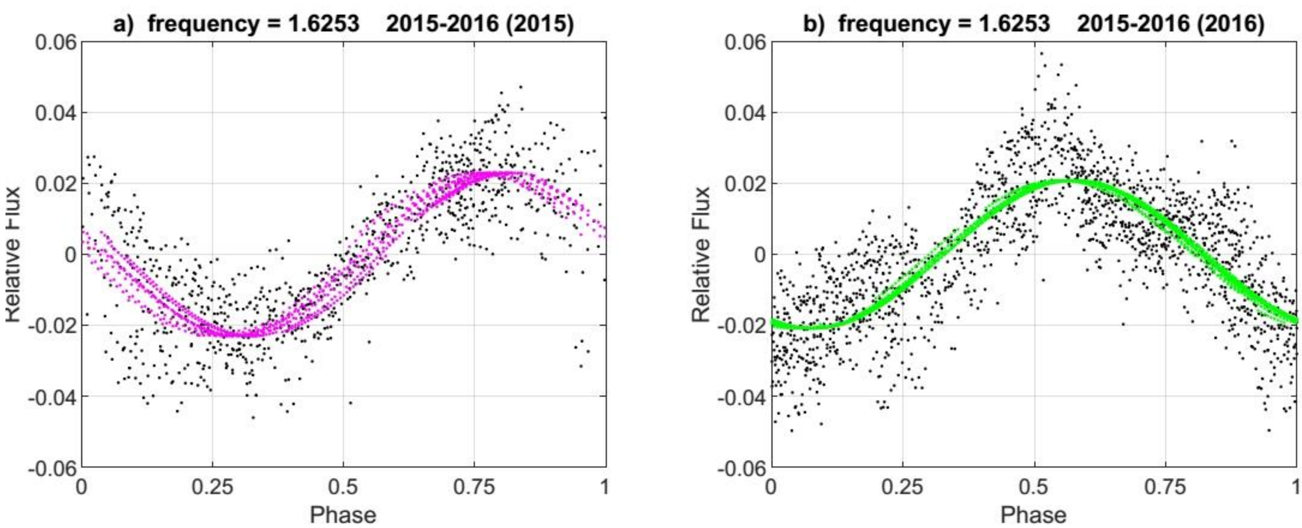


Fig 12. Phase plots for (a) 2015 and (b) 2016. See table 5 for details.

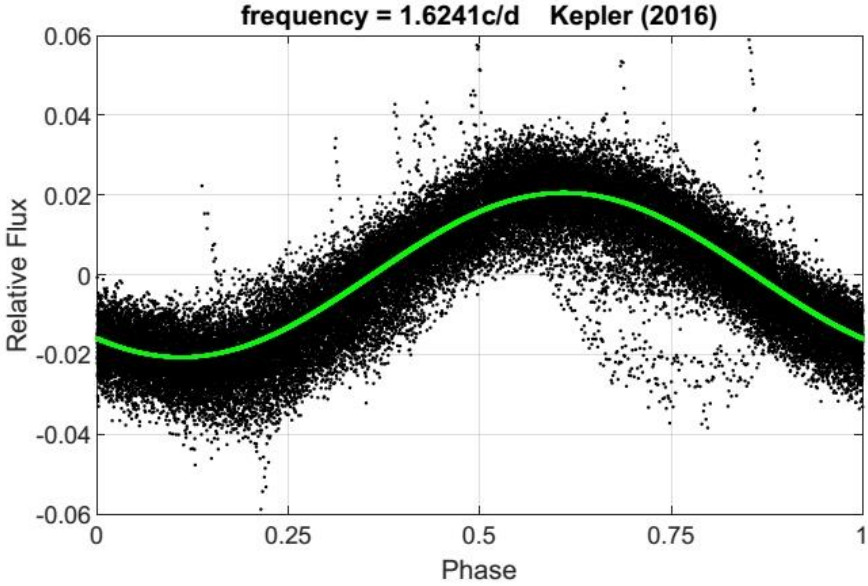


Fig 13.

Kepler Phase plot for 2016. See table 5 for details.

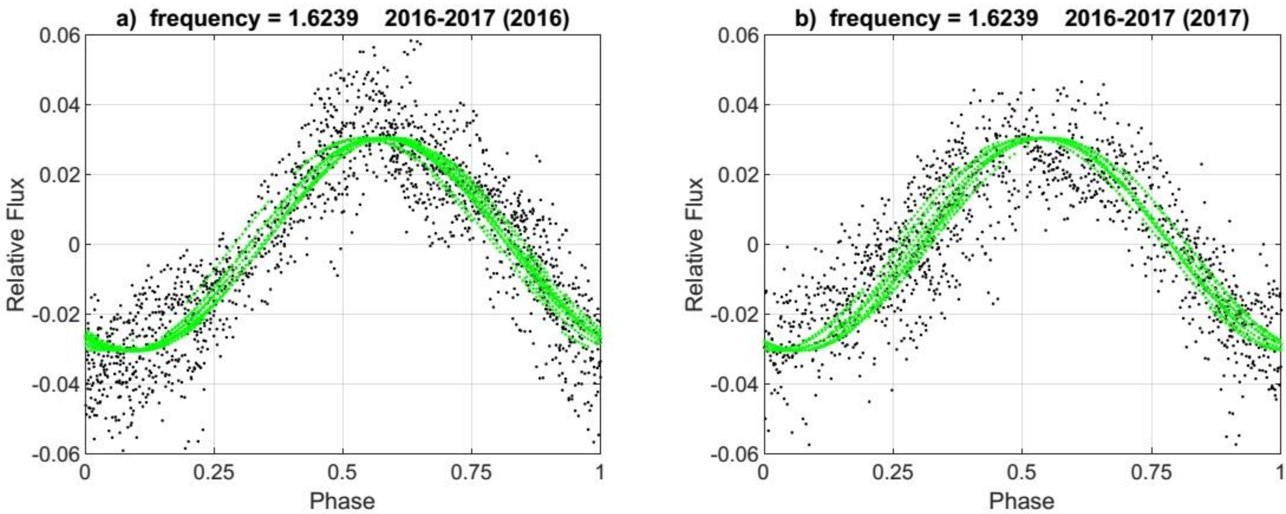


Fig 14. Phase plots for (a) 2016 and (b) 2017. See table 5 for details.

<u>Phase Plots - GROUP C</u>

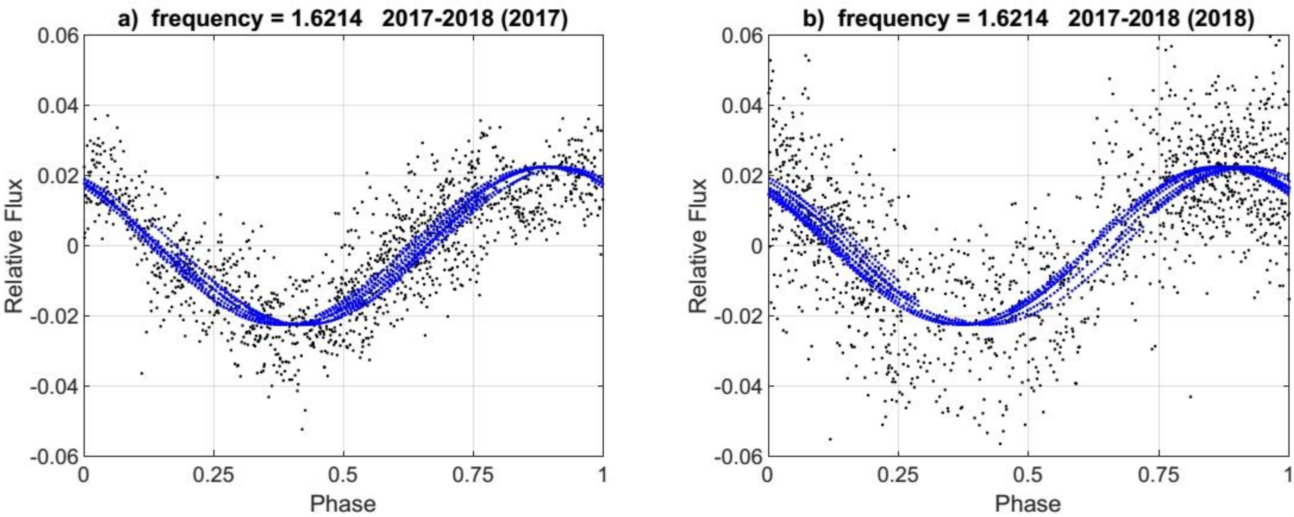


Fig 15. Phase plots for (a) 2017 and (b) 2018. See table 6 for details.

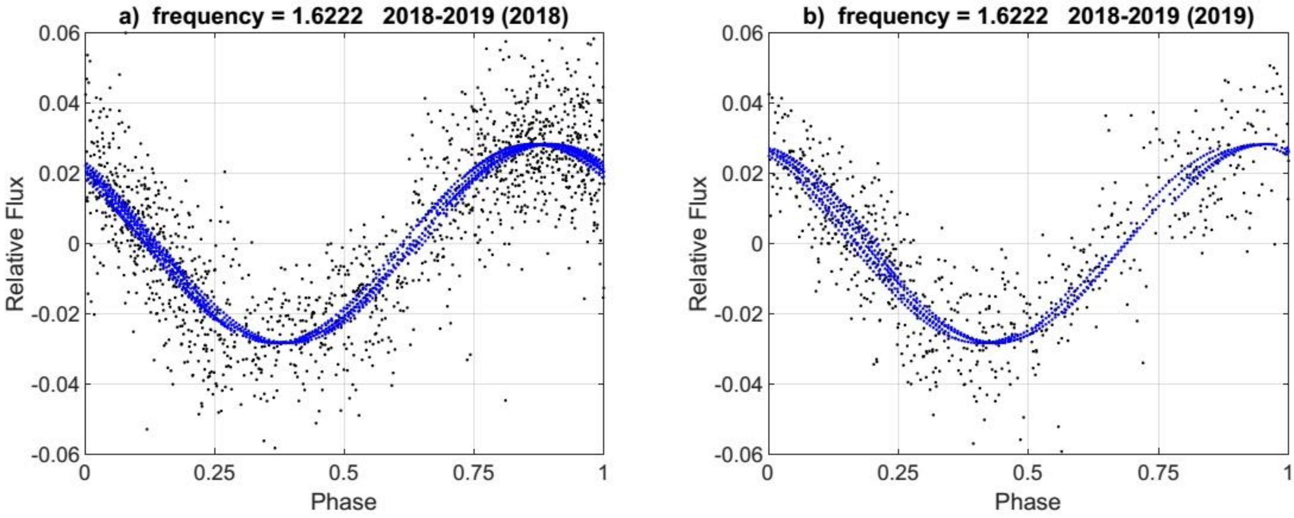


Fig 16. Phase plots for (a) 2018 and (b) 2019. See table 6 for details.

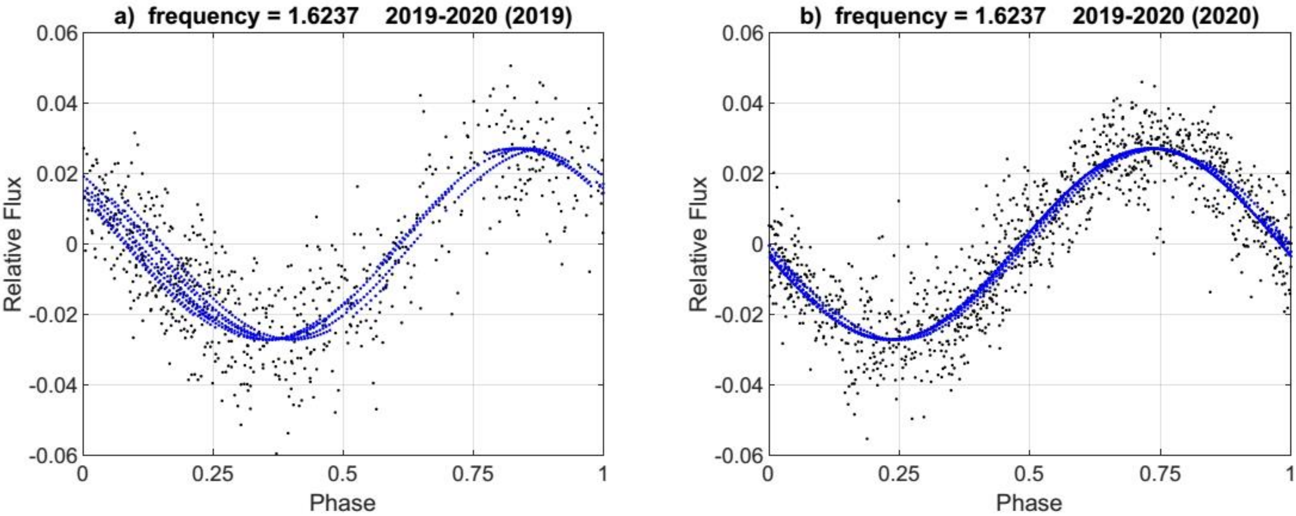


Fig 17. Phase plots for (a) 2019 and (b) 2020. See table 6 for details.

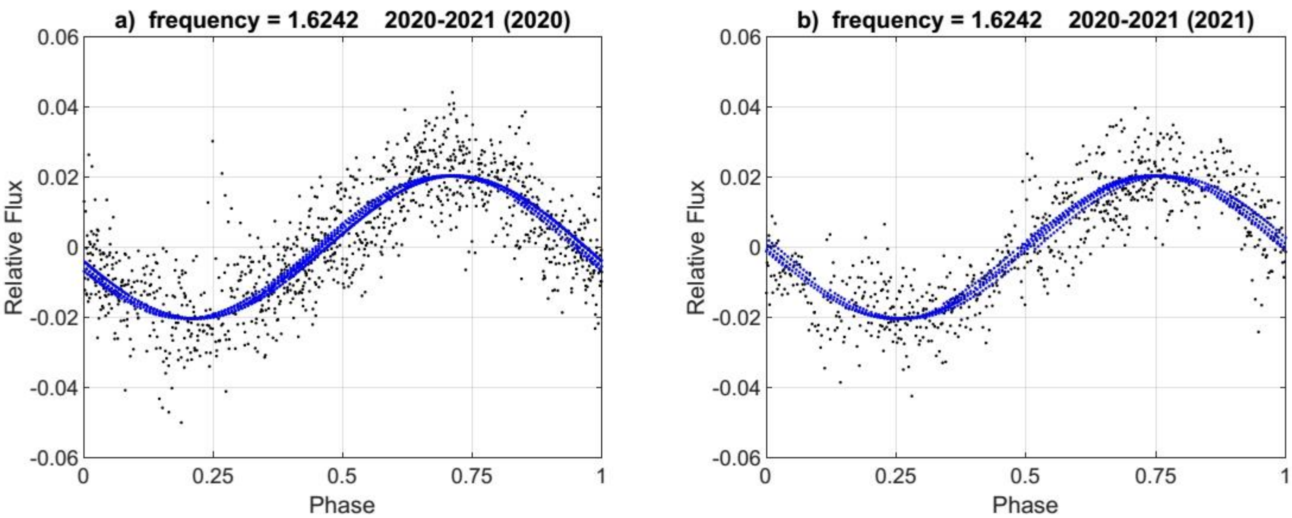


Figure 18. Phase plots for (a) 2020 and (b) 2021. See table 6 for details.

Another bolide seen from the Western Cape, SAFC #412

Tim Cooper[1], Peter Hers[2] and Francois le Roux[3]

1. ASSA Director, Comet, Asteroid and Meteor Section, 2. ASSA Garden Route Centre, 3. Hartenbos, Western Cape

Definition of terms

Commission F1 of the IAU on 30 April 2017 approved a number of definitions in relation to meteor astronomy*. A solid natural object of a size roughly between 30 µm and 1m moving in, or coming from, interplanetary space is termed a meteoroid. The light and associated physical phenomena (heat, shock, ionisation), which result from the high speed entry of a solid object from space into a gaseous atmosphere is termed a meteor. A meteor brighter than absolute (distance of 100 km) visual magnitude –4 is termed a bolide or a fireball. A meteor brighter than absolute visual magnitude –17 is also called a super-bolide. Any natural solid object that survived the meteor phase in a gaseous atmosphere without being completely vapourised is termed a meteorite.

*https://www.iau.org/static/science/scientific_bodies/commissions/f1/meteordefinitions_approved.pdf

Introduction

In recent years a number of bright bolides have been reported (Figure 1) from southern Africa, some of which may potentially have deposited meteorites. Analysis of very bright fireballs is important in order to determine the fall location of any possible meteorites if the impacting object survives to reach the ground. In particular video clips give a permanent record of the path, which can be calibrated after the event to accurately determine the pre-atmospheric orbit, path above the Earth's surface, location of events along the path, and potential strewn field location of any surviving fragments. The success of this methodology was well demonstrated for the bright super-bolide of 2 June 2018, from which several videos were analysed and confirmed a strewn field location in the Central Kalahari Game Reserve. A subsequent search at the indicated location resulted in discovery of twenty-two fragments from the impacting body, asteroid 2018 MA, now known as the Motopi Pan meteorite (Cooper 2021).

There have been a number of sightings in the last decade from the Western Cape. Most notable was the Daylight fireball of 12 March 2013, #288 in the Southern African Fireball Catalogue (SAFC) which was detected by US Government sensors, labelled No.1 in Figure 1, and disrupted 86 km west of St Helena Bay with a calculated total impact energy of 0.1 kT (Chamberlin 2022). More recently, several very bright fireballs were seen from the Western Cape; on 16 January 2019 (SAFC #316), 9 August 2021 (SAFC

#401), and 24 September 2021 (SAFC #403). All three of these potentially dropped meteorites, but in no cases were videos obtained that could be calibrated with sufficient accuracy to enable location of potential strewn fields. A further bright bolide was observed from the Western Cape on the early morning of 18 June 2022 (SAFC #412, this event), and while some useful video footage was obtained that enabled determination of at least a tentative direction of the disruption, all indications are that any potential meteorites would have fallen some considerable distance south of the coast. Nevertheless, analysis of video footage and eyewitness accounts is made here. All times were converted to UT unless stated. Descent angles are given in degrees, with directly upwards = 0°, horizontally left to right = 90°, directly downwards = 180° and horizontally right to left = 270°.

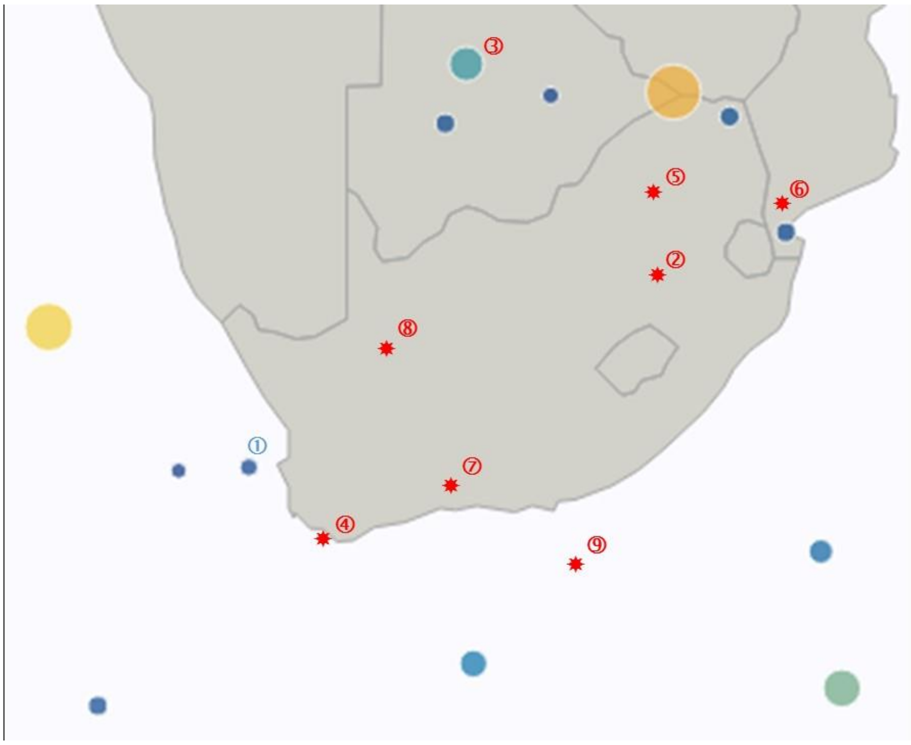


Fig 1. Locations of recent very bright fireballs or bolides. Diagram adapted from (Chamberlin 2022). Coloured dots are events detected by US Government sensors, size and colour indicate equivalent energy. Red stars indicate events investigated and included in the SAFC, but were not registered by US Government sensors. 1 = SAFC #249, Daylight fireball of 12 March 2013, Western Cape; 2 = SAFC #288, 15 June 2017, Eastern Cape, Free State, KwaZulu Natal, Gauteng, Mpumalanga; 3 = SAFC #305, 2 June 2018, asteroid 2018 MA, Gauteng, Limpopo, North West, Free State, Botswana; 4 = SAFC #316, 16 January 2019, Western Cape; 5 = SAFC #338, 18 March 2020, Free State, Limpopo; 6 = SAFC #367, 13 September 2020, Mpumalanga, Mozambique; 7 = SAFC #401, 9 August 2021, Western Cape; 8 = SAFC #403, 24 September 2021, Western and Northern Cape; 9 = SAFC #412, 18 June 2022, Western Cape, this event.

Analysis of video footage

Four videos were posted online, and provide the best information on duration and nature of the disruptions. Video 1 from an undisclosed location north of Cape St Francis shows almost the entire passage of the meteor from the time ablation started until it burned out just above the horizon. Screen grabs showing the nature of the fireball are shown in Figure 2. Unfortunately, the exact location of the camera could not be determined to enable the azimuths and altitudes of events along the path, but the meteor descends right to left with descent angle 240° and duration of visibility is 8 seconds, although the exact endpoint as the meteor passes below distant trees is obscured. The video shows several outbursts in brightness, the main disruption at about 5 seconds after start of ablation. The meteor is seen to be fragmenting already prior to disruption, see for example third frame from top right, and individual fragments can be seen as the meteor is fading out, see second last frame bottom left.

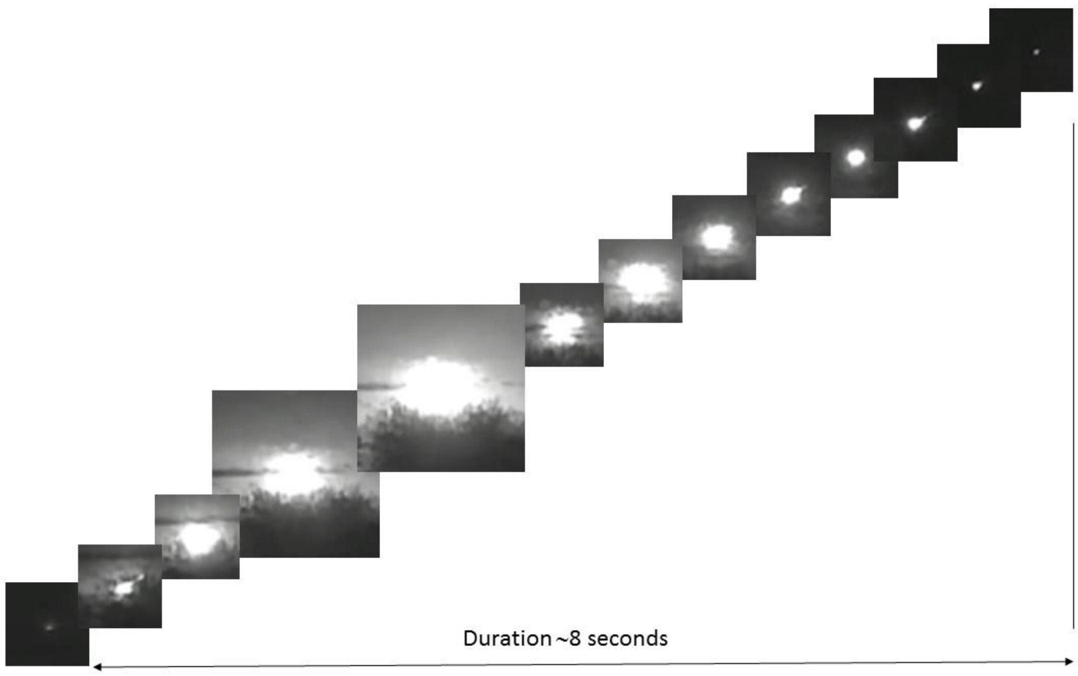


Figure 2 Appearance of fireball as captured by video north of Cape St Francis, exact location not given. Original video shows several outbursts in brightness, the main one at 5 seconds into ablation. Descent angle is 240°.

Video 2 (not shown) was posted on social media, from a camera located in Dana Bay pointed roughly towards south across the sea. The reflection of the fireball can be seen on the water, first in azimuth 158° as it quickly brightens, and followed by four or five distinct outbursts in brightness, the main one in azimuth 143°. Thereafter the fireball can be seen directly as it comes into view in azimuth 128°, with two distinct fragments, the leading one largest, before burning out just above the horizon in azimuth 126°. The duration is 6 seconds, but ablation was already in progress when the fireball's reflection came into view towards the right of the field of view.

Video 3 was supplied by Michael Simon from a camera located at Cola Beach, Sedgefield. The video shows the bright flash takes place just outside the field of view at right, which is in azimuth 153°, then enters upper right, moving right to left with a descent angle of 242°. The fireball is lost from view as it dips below a distant ridge in azimuth 148°, altitude 7°. The visible passage is shown in Figure 3, and after the bright flash three or four fragments can be seen trailing the main body, see for example bottom two frames.

Figure 3 Appearance of fireball from Cola Beach, Sedgefield, reproduced courtesy of Michael Simon. Descent angle = 242°. Note the distinct fragments trailing the main body after the main disruption.

Video 4 (not shown) was posted from a camera looking south from Brenton on Sea. This video only shows a short section of the path, and the meteor is only seen in reflection, with a bright flash appearing in azimuth 161°.

The various directions determined from the three videos whose locations were known are shown in Figure 4. Unfortunately they are located fairly close together geographically and consequently have small coincidence angles, and the absence of videos from further east limits the determination of actual longitude and latitude positions of the disruption and termination of the impacting body. Nevertheless, and considering termination was low above the horizon, we assume the event occurred far offshore and slightly east of Plettenberg Bay.

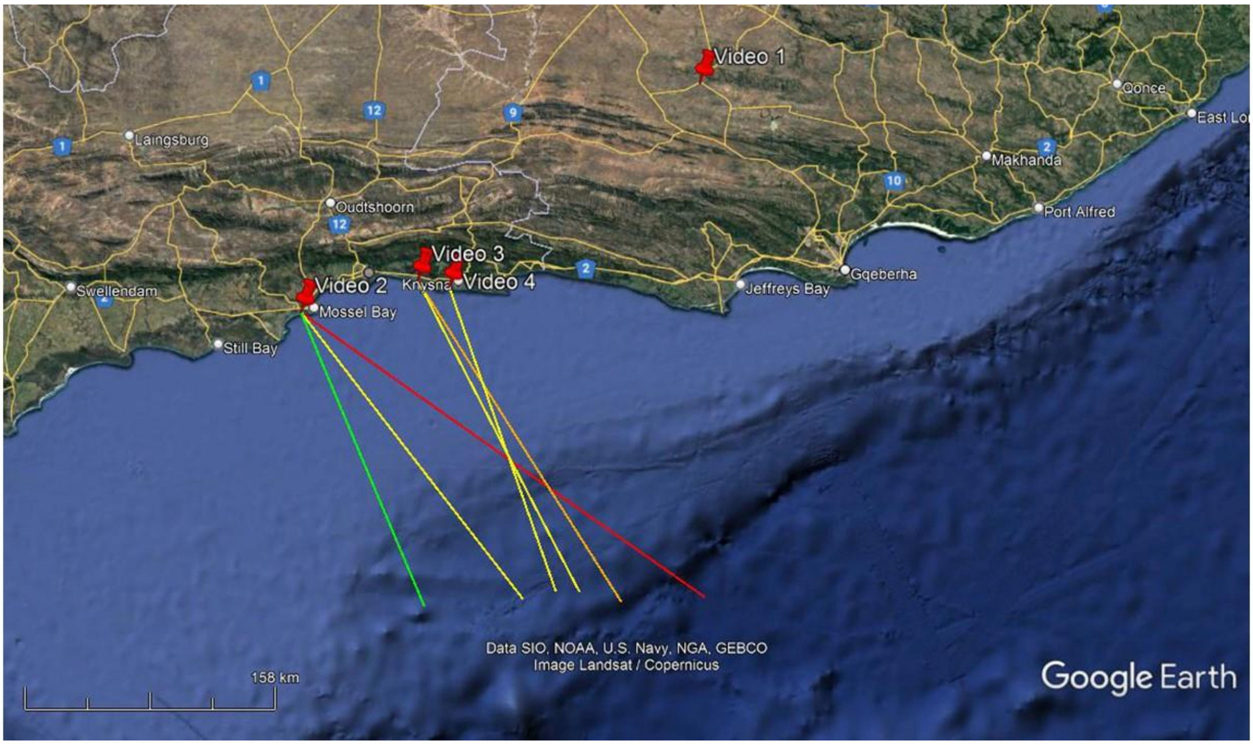


Fig 4. Locations of video cameras and directions to events in the path of the fireball. The direction of the events can only be determined from videos 2-4. The yellow line from video 2 is the direction of the flash, and the red line from video 2 is the direction visible light from the fireball terminates. The bright flash occurs at or immediately before the yellow line from video 3, and the orange line is the point at which the fragmented body passed below a nearby ridge. Hence the actual termination is just past this direction.

Eyewitness accounts The following reports were received in order from west to east. The most westerly report was from Francois le Roux at Hartenbos, who gave the time as 03h47, having just switched off his early morning alarm, when the interior of his bedroom was lit up by a bright light. Looking through the window he saw four or five large fragments, estimated $m_v = -5$ to -4, decreasing in brightness and apparent size from leading to following and descending right to left, evenly spaced 'like pearls on a string'. Note the similarity of this description to the image in Figure 3. From descriptions relative to nearby landmarks we estimated the path from azimuth/altitude 145°, 15° to 132°, 10°, where the fragments disappeared behind a nearby hill. No further explosions were seen after they had passed out of sight. Colour was bright yellow with definite red outlines. The bodies did not fragment further and no further explosions or other flashes were observed after the initial one. The total duration after the initial flash was 2-3 seconds.

Louis Olivier was driving from Friemersheim towards Tergniet headed in direction 169° when the sky lit up, and he saw the fireball with a long tail, duration about 3 seconds, before burning out over the ocean. From a sketch provided the path was very approximately from azimuth 186° to 160°, fairly flat trajectory at perhaps 15-20° altitude above the horizon.

Talita and Theo van Zyl were cycling near Swartvlei in a southerly direction, separated by 110 metres on the road and witnessed the bolide independently. They both logged reports on the AMS Fireball Report page (AMS Fireball Event 3490-2022). Talita noted the time on her GPS as 03h47m55s, which can be considered the most accurate time of event. She gave the path as azimuth/altitude 207°, 45° to 157°, 30°, which gives a descent angle of 248°, duration 3-4 seconds, 'I don't know if I heard a sound, it was over so quickly. It was so unexpected, right in front of us while training'. Estimated magnitude −17. Looked like a neon-green flare with orange/yellow sparks behind it. Theo gave the path as 214°, 45° to 162°, 21°, which gives a descent angle of 230°, duration 3-4 seconds, very bright and [looked] almost unreal, estimated magnitude −16, colours seen were orange and green, fragmented into orange fragments. Lisa de Villiers-Evers was travelling south-east towards George Airport when at about 03h50 she noticed a green coloured light which developed a tail about 45° above the horizon, duration about 10 seconds, 'but did not see any explosion, it just disappeared.' It would appear Lisa witnessed the entire passage and her duration of the visible meteor is in line with that determined from Video 1.

Brett Burgel from Sedgefield heard a loud but distant crack at 03h47, 'I thought it was a branch breaking'. As he opened his driveway gate he saw an orange red trail out over Sedgehill, which is in direction 164°, moving towards the east and out to sea. 'It was about 25-30° above the horizon and disappeared very quickly'. Also from Sedgefield, Willemien van der Walt gave the time as 03h49, seeing '2 seconds of very bright white light over the ocean to the south'. Dolla Lerm at Cola Beach also saw it through a bedroom window, duration 'a few seconds, and it seemed to disappear into the sea'. The apparent close proximity of bright meteors is an optical illusion, but her comment indicates nevertheless that the termination was at low altitude above the horizon, giving the appearance that it reached the surface.

There were several reports from the Knysna area. Russell and Gretchen Wheeler saw the fireball from Brenton Ridge, were sitting in bed and at 03h49 saw through a south facing window 'a huge orange burning fireball with fiery tail. It lit the whole sky and also had smaller 'particles' breaking off it. It was remarkable as it illuminated the whole area, like daylight. Duration about two seconds, but the view was limited by the window'. They produced a sketch which showed the path from azimuth 191° to 160° and Russell estimated it was less than 10° above the horizon. Sally Mott from Eastford Ridge, 'saw the fireball from a bedroom window. It was travelling west to east, duration a few seconds, green in colour but with an amber fire like glow at the back. It lit up the bedroom'. Monique Winn was sitting outside at the time facing south when the meteor appeared from her right and burned out in the direction of the lagoon, which is azimuth ~153°. 'It had a bright green broad tail, was big and lasted about 4-6 seconds. It seemed low when it disappeared but it happened so quickly, I was awestruck and so it is hard to be precise'. Antonie van Tonder sent a report to the AMS Fireball Report page, 'my first thought was lightning as it was as bright, time 03h47, duration 3-4 seconds, path from azimuth/altitude 221°, 71° to 165°, 16°, magnitude –17, colours given were blue, green, yellow, pink and white. 'Terminated with three bright explosion-type events, fragmented into fifty or more fragments in lots of neon colours and then burned out'.

Tracy-lee Grant saw the fireball from Signal Hill View Point, Plettenberg Bay. She gave the time as 03h50, and it looked like it was over Robberg [azimuth ~208°]. 'It lit up the whole sky when it exploded and then dissipated into an orange fiery line before disappearing'.

The most easterly report was from Emily Davis at Cape St Francis. She was walking down an outside staircase at around 03h45, when she saw the fireball 'roughly the size of a pea to the eye' burning red with bright orange tail, and moving towards east out over the ocean. From indications on a map of the location Emily estimated it terminated about azimuth 214°.

The locations and various directions determined from those who saw the fireball are shown in Figure 5. Most did not see the fireball from the start, but from the most westerly sightings ablation commenced to the south of Still Bay. From the most reliable reports, the direction of termination was to the south of Plettenberg Bay.

Discussion and conclusions

A bright bolide was seen over a narrow region of the Garden Route of the Western Cape at 03h48 UT on Saturday June 18, 2022. The path was possibly a few hundred kilometers south of the coast, starting to the south of Still Bay, and terminating south of Plettenberg Bay, or possibly further east, and at least further than longitude 23.5° E. Duration of passage from video records, and at least one visual report was around 8 seconds. The object began to fragment early in its path, underwent four or five outbursts in brightness, with the main disruption occurring at around 5 seconds, after which four or five large fragments continued until ablation ceased. The most predominant colour reported was green, especially before disruption, but with more reports of yellow and orange for the fragments remaining after disruption as the meteor decelerated and was seen at lower altitude. Video records certainly seem to indicate the brightness exceeded the brightness of the full moon ($m_v > -13$), though the footage was not calibrated. Three eyewitness accounts gave the brightness as magnitude −16 to −17, or about 15-40 times the brightness of the full moon. While it is difficult even for experienced astronomers to estimate magnitudes at this level, if correct the object would have reached sufficient brightness to be classed as a super-bolide.

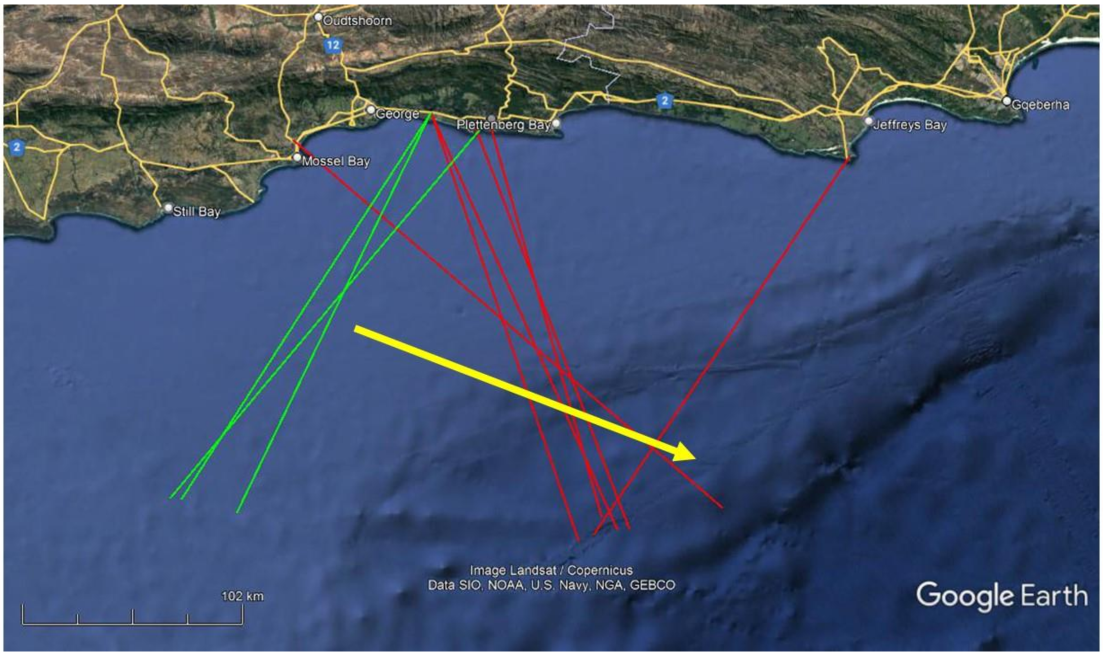


Fig 5. Locations of visual sightings and directions to first visibility (green lines) and termination (red lines) of the fireball. The possible path as determined from the video measurements is shown as a yellow arrow, and the visual reports are in good agreement, but nevertheless the actual angle and trajectory are uncertain.

Acknowledgements

The authors would like to thank Robert Lunsford, American Meteor Society, for forwarding reports of AMS Fireball Event 3490-2022 from the AMS website. Figure 1 is adapted from Chamberlin (2022). Figure 3 is reproduced with kind permission of Michael Simon. Figures 4 and 5 were prepared from Google Earth images downloaded 7 July 2022, credit to Google and AfriGIS (Pty) Ltd.

References

Chamberlin, A. B., 2022. Fireball and bolide data, Jet Propulsion Laboratory, Centre for Near Earth Object Studies (CNEOS) webpage at https://cneos.jpl.nasa.gov/fireballs/, accessed on July 7, 2022.

Cooper, T. P., 2021. The super-bolide of June 2, 2018 and meteorites from asteroid 2018 LA, *MNASSA* **80**, pp77-103.

Recent Southern African Fireball Observations Events # 406-415

Tim Cooper, Director, Comet, Asteroid and Meteor Section

This article continues the sequential numbering of reported fireball sightings from southern Africa. By definition, a fireball is any meteor event with brightness equal to or greater than visual magnitude (m_v) –4. The following events were reported to the author and details are reproduced as given by the observer [any comments by the author are given in brackets]. Where the report originated from the American Meteor Society Fireball page, the corresponding AMS event number is given. All times were converted to UT unless stated, and all coordinates are for epoch J2000.0. Descent angles, if given, are in degrees, with directly upwards = 0°, horizontally left to right = 90°, directly downwards = 180° and horizontally right to left = 270°.

Event 406 – 2021 December 27 – Hermanus, Western Cape
Observed by Danie van der Spuy at 19h44. Brighter than Venus, $m_v \sim -5$, colour off-white, duration about 3 seconds, path from 210°, 25° to 212°, 0° [ocean horizon] that is RA/Decl. 20h36, –62° to 18h35, –45°. There were no signs of disintegration and no sounds heard.

Event 407 – 2022 January 20 – Roodepoort, Gauteng
The fireball was observed independently by three people, who were all located within 2 km of each other.

Observed by Christiaan de Jager at about 20h00, bright white/orange fireball, appeared to be flaming, duration 2 seconds and left a persistent train, path from az/alt 10°, 30° to 350°, 25° where it appeared to just burn out. These positions correspond to RA/Decl. 06h32, 33° to 05h10, 39°.

Observed by Rosemary Attwell, duration 3-4 seconds, she saw the colours as blue and white, and estimated the brightness as greater than the moon, which had just risen and was then 92% illuminated, magnitude –11 after correcting for extinction, altitude 5° in azimuth 70°. The fireball left a persistent train visible for 2 seconds. Path from az/alt 41°, 69° to 339°, 47°, that is RA/Decl. 06h48, –10° to 04h52, 15°.

Observed by Tania van den Berg, duration 3-4 seconds, $m_v = -5$, bright yellow/white fireball which left a persistent train for one second, and Tania said was 'just magnificent to see'. Path from az/alt 20°, 67° to 348°, 12° where it disappeared behind trees, that is RA/Decl. 06h24, –04° to 04h34, 50°.

Two of the three trajectories are similar but differ in altitude, but all three agree the fireball was seen in a northerly direction, descending from right to left. Since the observed times are also uncertain, the radiant position cannot be determined with any certainty. AMS Report 943-2022

Event 408 – 2022 March 12 – Lake Kariba, Zimbabwe
Observed by Steve Edwards at 18h58 from Musango Island Safari Camp Lake Kariba. Path from azimuth 45°, altitude not confirmed, to az/alt 68°, 10°, and therefore moving left to right and terminating just above the horizon close to the star alpha Comae Berenices. Path started below right of the moon which was then at altitude 44° in azimuth 342°, and magnitude –11.4. Quite bright to start with, seemed to fade then brightened almost immediately to a very bright fireball. Duration 4 to 5 seconds, enough time to point it out to some guests who had their backs to it. Colour greenish-white burning into an intense bright white. Persistent trail 3 seconds. No fragmentation. Two guests reported crackling sound almost immediately after the fireball, but Steve did not hear any sounds.

Event 409 – 2022 March 31 – Firgrove, Cape Town, Western Cape
Observed by Kobus Kapp at 19h15, bright yellow white fireball, $m_v = -5$, 'I was driving on the R44 in a Southerly direction [heading 236°] from Stellenbosch to Somerset West when I noticed it in my field of vision from the top of the windscreen, fragmenting just before disappearing'. Duration 3-4 seconds, path approximately from az/alt 243°, 51° to 239°, 15°, that is RA/Decl. 05h47, –42° to 02h48, –34°. AMS Report 2136-2022.

Event 410 – 2022 May 21 – Sandton, Gauteng
Observed by Christo Grobler at 20h52, duration 3-4 seconds, said to be as bright as the full moon (not visible at the time). Colours mentioned were yellow, green and blue, and the fireball left a yellow train for 10° of its path, turning white with duration one second. Path from az/alt 44°, 59° to 55°, 20°, that is RA/Decl. 16h05, –03° to 18h20, +20°, path length 40°. Christo said 'it was amazing coming down straight to earth and [duration] was so long in seconds that I couldn't believe it was a meteor'. AMS Report 3003-2022.

Event 411 – 2022 June 8 – Various, Gauteng, KZN, Mpumalanga
Observed by Ryan Erasmus in bright daylight, shortly after 06h00, duration about 0.5 seconds, descending vertically in azimuth 208°, from altitude 18° to 5°, that is RA/Decl. 18h20, –63° to 16h52, –56°. Ryan said 'it had a very large ball at the head and clear tail or streak'. Colour was a very bright blue with slight green tinge, and the object was clearly visible against the bright blue sky. 'It's the brightest object I have ever seen, even compared to any nighttime object'.

Jenny Koen and Stephen Botha were travelling on the N2 towards Harding, in direction NW, when they saw a bright blue-green fireball, duration less than 1 second, moving right to left with a flat trajectory and low above the horizon in azimuth about 300°. There was bright sunlight and no clouds. Jenny said the 'blue green colour was particularly striking'.

Piet van Wyk was travelling on the R35 from Bethal to Morgenson when he saw the fireball as a bright blue streak from azimuth 210°, descending right to left from 40° to 15° above the horizon. Piet gave the time as 06h07 and duration was about 3 seconds.

The observations give a path passing overhead the towns of Sasolburg and Kroonstad, possibly ending near Bloemfontein. There were no reports of fragmentation or explosion, and no reports of any sounds were received.

Event 412 – 2022 June 18 – Various, Western Cape

Many reports were received of a bright bolide seen from the Garden Route region of the Western Cape at 03h48. A full report can be found elsewhere in MNASSA, from which the following is concluded. The path was possibly a few hundred kilometers south of the coast, starting to the south of Still Bay, and terminating south of Plettenberg Bay, or possibly further east, but at least further east than longitude 23.5° E. Duration of passage from video records, and one visual report was around 8 seconds. The object began to fragment early in its path, underwent four or five outbursts in brightness, with the main disruption occurring at around 5 seconds, after which four or five large fragments continued until ablation ceased. The most predominant colour reported was green, especially before disruption, but with more reports of yellow and orange for the fragments remaining after disruption as the meteor decelerated and was seen at lower altitude. Video records would indicate the brightness exceeded the brightness of the full moon ($m_v > -13$), though the footage was not calibrated. Three eye witness accounts gave the brightness as magnitude –16 to –17, or about 15-40 times the brightness of the full moon. AMS Report 3490-2022.

Event 413 – 2022 June 28 – Cape Town, Western Cape

Observed by Kobus Kapp at 16h40, $m_v = -5$, orange/red fireball, duration 1-2 seconds, path from az/alt 210°, 36° to 190°, 22° that is RA/Decl. 07h13, –65° to 03h01, –75°, from Volans to Hydra. Fragmentation obvious, not spectacular. AMS Report 3718-2022.

Event 414 – 2022 July 13 – Edenvale, Gauteng

Observed by Andy Overbeek at 21h30, $m_v = -4$ to –5, blue-white colour, fragmented into two pieces with the larger fragment preceding, duration 3-4 seconds, path horizontally from az/alt 0°, 45° to 45°, 45°, that is RA/Decl. 18h49, +19° to 20h50, +08°.

Moon was near full, magnitude –12.4, altitude 78° in azimuth 92°. It was partly cloudy at the time and cloud obscured part of the passage.

Event 415 – 2022 August 2 – Garden Route, Western Cape
There were several reports on social media pages of a bright meteor, said to be brighter than Venus, seen over the same area as event 412. Reports were received from (west to east) Knysna, Plettenberg Bay and St Francis Bay. Times given were between 16h15-16h20 during evening twilight, the Sun was 6° below the horizon but most stars were already visible.

At Knysna Joan and Stan Truby said 'we were walking up Bolton Street [direction 145°] and looking up the street there are tall trees either side. We may have seen it for about 3 seconds moving east at about 20° inclination from the horizontal. It was an orange colour and it was large; the size of a flare. It moved quickly across the part of the sky that we could see'.

Near Plettenberg Bay, Mélanie Hrabar was walking her dog at Reed Boardwalk looking in direction of Whale Rock and Robberg, the fireball moved along the length of Robberg, about 25-30° altitude from azimuth 180° to 130°. Duration estimated as 5-8 seconds, yellow and white, but initially with some red colour, very long tail of about 20°, and faded slowly. Shaylee Westhead was walking in Roxanne Street in direction 112°, when she saw an orange ball with misty-white tail, which she said 'looked like a comet'. The tail was discontinuous (see-through) in the middle and tapered to a sharp point. Speed said to be 'as fast as an airplane, but appeared larger and higher'. Appeared to be moving towards the ocean, and disappeared before it reached the horizon. Rudolph Nel saw the fireball from Poortjies, duration 5 seconds, bright orange colour, and travelling about 15° above the horizon towards east. It faded very quickly without disintegration.

From Keurboomstrand, Sue Scheepers saw it from the top of a dune at low altitude above the horizon; 'it was not much higher than I was, travelling over the sea in an easterly direction. Bright yellow ringed with red. No sounds heard and fast moving, by the time she looked to take a photo is was gone. Paula Slabbert also saw the fireball from Keurboomstrand, said it 'was magnificent to see', travelling south, low above the horizon from about azimuth 230°, slow moving and 'looked like a huge shooting star continuing to burn for very long'. Rudi Mostert also observed from Keurboomstrand, 'looked like a really bright shooting star' moving west to east and offshore. He gave the duration as about 30 seconds before slowly fading away.

Acknowledgments
AMS reports are courtesy of Robert Lunsford (Secretary General of the IMO). I thank Peter Morris for continuing to forward details of fireball events from Zimbabwe. Peter

Hers and Francois le Roux are thanked for the considerable efforts they put into assisting with Event 412. Peter Hers also coordinated reports of event 415.

Colloquia

Colloquia and Seminars (now Webinars) form an important part of a research facility, often as a sort of pre-publication discussion or a discussion of an individual's current research, and as such it is virtually impossible to "publish" this material. However by recording the topics discussed in the form below does indicate to those, who are unable to attend, what current trends are and who has visited to do research: it keeps everyone 'in the loop' so to speak
These form an important part of a research facility, often as a sort of pre-publication discussion or a discussion of an individual's current research, and as such it is virtually impossible to "publish" this material. However, by recording the topics discussed in the form below does indicate to those, who are unable to attend, what current trends are and who has visited to do research: it keeps everyone 'in the loop' so to speak
With the advent of CV19, these Colloquia and Seminars are being presented to wider audiences via Zoom and other virtual platforms. The editor has started by identifying what would originally been "local" Colloquia and Seminars; not easy as there are now Webinars on interesting topics from around the globe! In time we will either return to the traditional Colloquia and Seminars or many will become Hybrid session.

Title: Measuring the Effect of the Cosmic Web on Galaxy Evolution properties + Other stories
Speaker: Munira Hoosain, PhD Student, SAAO
Date: 7 July
Venue: SAAO – Auditorium/Zoom
Time: 11h00

Abstract: Galaxies transform from blue and star-forming to 'red and dead' through various processes related to their environment and their internal properties. Tracing neutral hydrogen gas, which is a crucial ingredient for star formation, can help us further our understanding of galaxy evolution. The cosmic web is the large-scale structure of the universe, which consists of filaments, clusters and voids. Filaments are important environments as they channel galaxies from low-density to high-density regions and have a small but measurable effect on galaxy properties.

In this talk, I will discuss my efforts to measure the effect of cosmic web filaments on the gas inside of galaxies and the overall effect on galaxy evolution using data from the ECO and RESOLVE surveys. Additionally, I will discuss my future PhD research measuring the Cosmic Neutral Hydrogen Density in the LADUMA survey and how it will impact our understanding of gas in galaxies.

Title: Unfolding the capability of future medium-size telescopes: First light of the SALTO demonstrator
Speaker: Dr. Jyotirmay Paul, Postdoctoral Fellow, University of Liege
Date: 11 July
Venue: SAAO – Auditorium/Zoom
Time: 11h00

Abstract: The adaptive optics technology unfolds the capability of a ground-based telescope. Last three decades the world has witnessed the successful operation of AO. Though the applicability, the complexity and cost have gone down in the last decade due to the advancement of deformable mirrors, wavefront sensors, and real-time fast computer technology. An autonomous Rayleigh scattered laser-guided single conjugated adaptive optics system called SALTO is made and demonstrated in Belgium for a 1-meter class telescope. This project gives the opportunity to rejuvenate the scientific goals of medium-class telescopes (1-3 m) with AO technology.
In this talk, we shall discuss the overall study of the design of the AO system, optical to control. We also discuss the integration and calibration of SALTO. In the end, on-sky successful results at 1.55µm under 2-3'' seeing are presented.

Title: Media training for scientists
Speaker: Thembela Mantungwa
Date: 28 July
Venue: SAAO – Auditorium/Zoom
Time: 11h00

Abstract: Thembela Mantungwa from the SAAO SALT collateral benefits division will present a session on media training for scientists. She will cover aspects of how a press release differs from a journal article, and provide us with helpful hints for in-person or television interviews about our work. This session will be useful for seasoned astronomers and student alike.

Title: Towards Precision Astrophysics for Warm Ionized Gas
Speaker: Prof Renbin Yan Chinese University of Hong Kong
Date: 4 August
Venue: SAAO – Auditorium/Zoom
Time: 11h00

Abstract: The interstellar medium is the fuel for star formation and AGN, and the sink for their feedback energy. It also records the history of star formation in its elemental abundances. The warm ionized gas is a major component of the ISM and has been extensively studied. However, there are still a number of mysteries about the

ionization mechanisms for such gas in quiescent galaxies and quiescent regions of galaxies. Even for star-forming regions which are most well studied, there are still a large number of discrepant results in the literature about their metallicity, their elemental abundance pattern, ionization states, and dust attenuation. I would present our efforts in solving these mysteries and resolving those discrepancies. Some puzzles got resolved but new ones arise. I will describe a roadmap towards an era in which we can model the astrophysics of warm ionized gas with precision, in the same style as Precision Cosmology. I will also introduce the design of a cost-effective, high spectral resolution, integral field spectrograph. When paired with a small telescope like a telephoto lens or arrays of them, it could provide unprecedented data to help us better understand star-forming HII regions and the feedback of star formation.

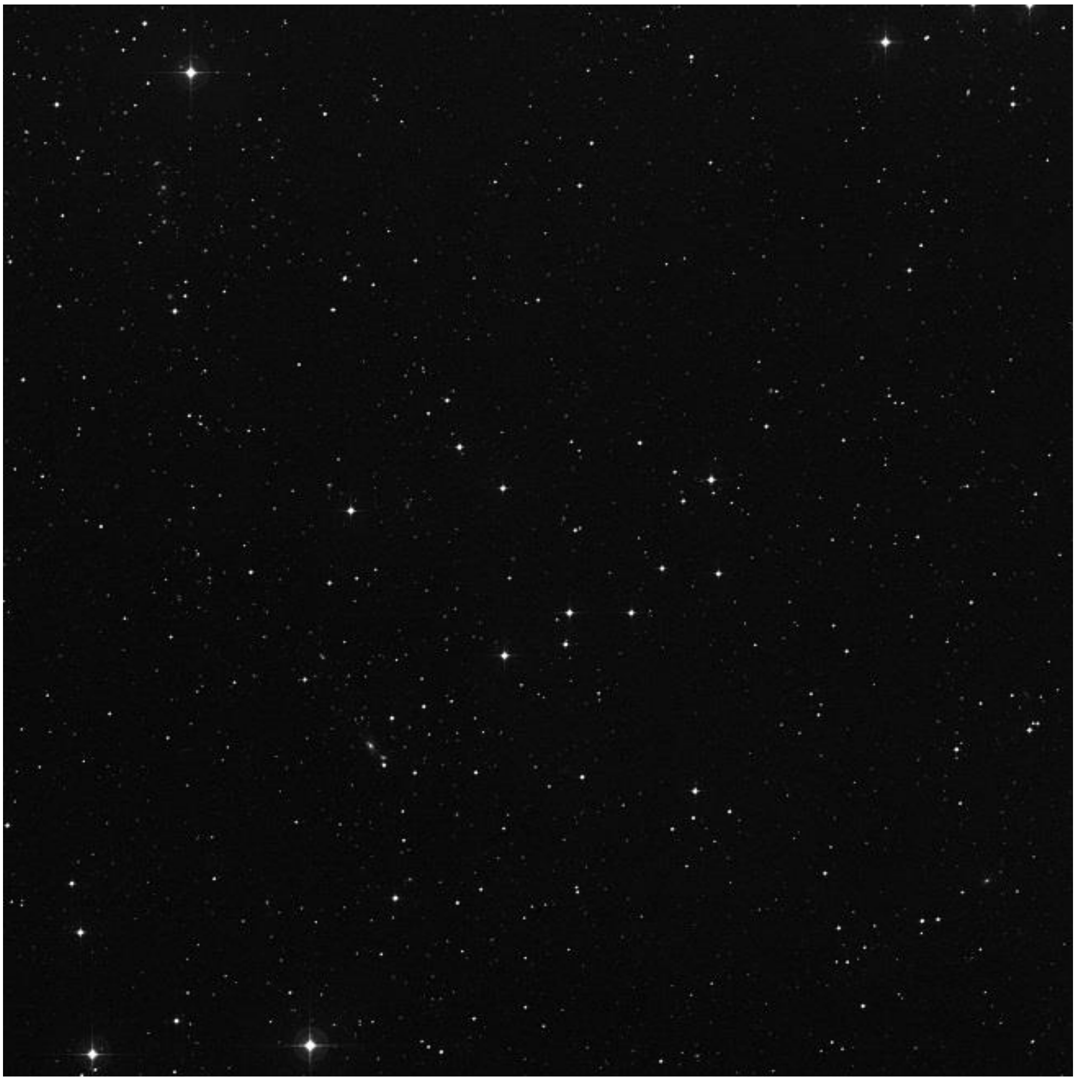
Title: Atomic Hydrogen disks as tracers of galaxy transformation in Abell 2626 and beyond.
Speaker: Dr Tirna Deb
Date: 12 August
Venue: UWC Seminar Hybrid/Zoom
Time: 11h00

Abstract: The extended, fragile, collisional atomic hydrogen (HI) gas discs in galaxies are excellent diagnostic tracers of gravitational and hydrodynamic processes in the cosmic environment they are residing in and also reservoirs for star formation. Within a galaxy cluster, both gravitational perturbations (tidal interactions, harassment, etc.) and hydrodynamic processes (thermal evaporation, ram pressure stripping (RPS), etc.) are at play. However, it is not clear yet which of these processes dominate the transformation of galaxies from star forming and gas rich, to quiescent and gas poor. I have investigated the influences of the global and local cosmic environment on the evolution of galaxies, both from the HI morphologies of galaxies in different locations of cluster substructures and the multi-wavelength case studies of the striking galaxies. From the new MeerKAT telescope observations of A2626 volume, I am studying the spatially resolved morphologies of the 219 HI detected galaxies, covering a range of cosmic environments. By identifying the cluster substructures and characterising their environments, I investigate the relative importance and effects of the various physical mechanisms that are responsible for reshaping galaxies. In addition, I am also studying the detailed cases of HI gas stripping in the "jellyfish galaxies", the extreme examples of RPS with in-situ star formation in the tails. I have analysed the multi-phase (neutral, molecular, ionised gas) ISM of jellyfish galaxies JW100 and JO204 from multi-wavelength MeerKAT or JVLA, MUSE and ALMA observations. I will talk about how HI observations contribute to understanding the multiphase gas stripping in these jellyfish galaxies.

Streicher Asterisms

Magda Streicher

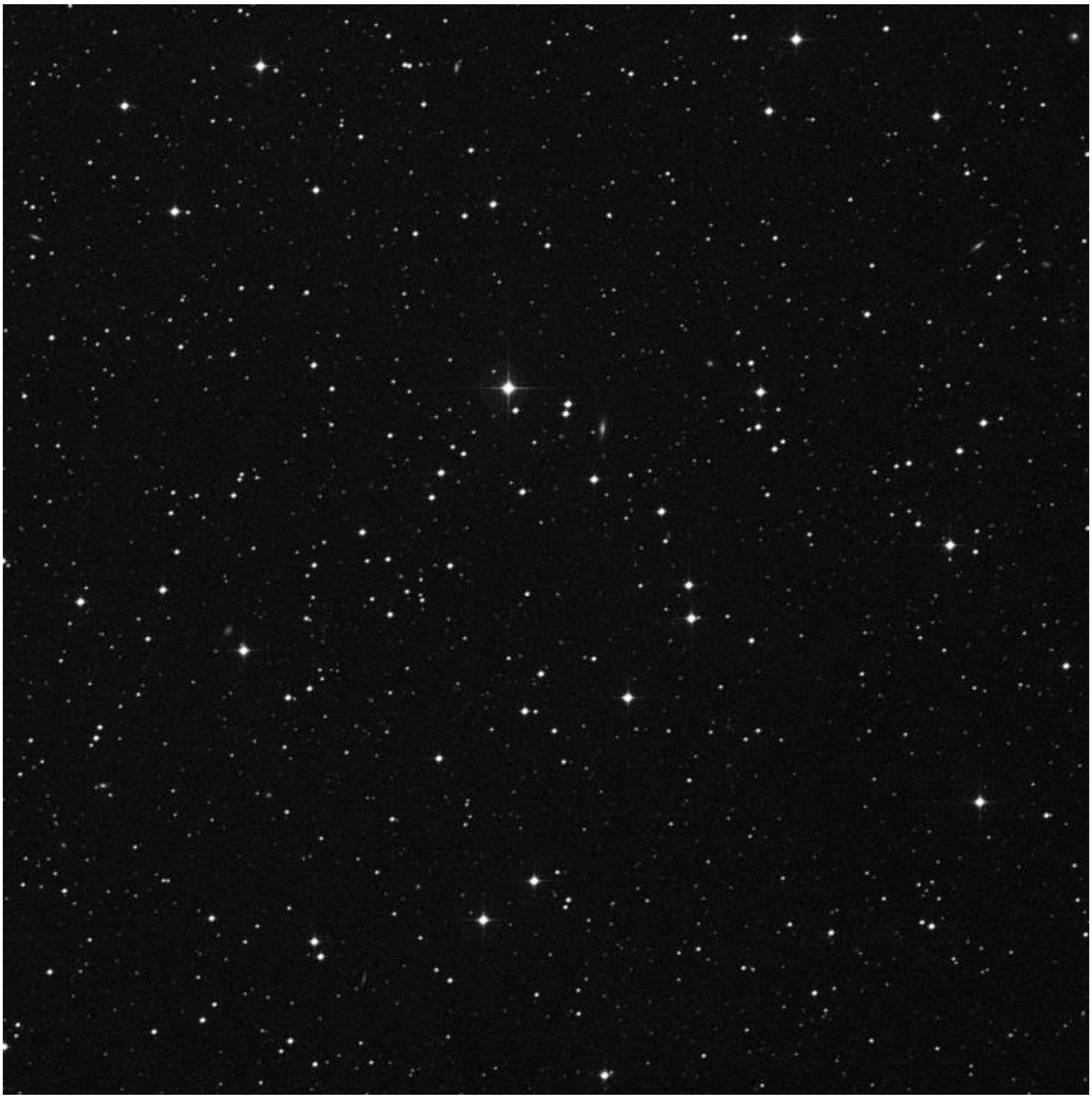
STREICHER 86 – DSH J0027.5-3517
Sculptor



In a way this is a near perfect zigzag consisting of six magnitude 11 stars evenly spaced from north-west to south-east. However, a few stars to the north spoil this shape in a way. The nice thing about searching out asterisms is the story-telling part of these small groupings with fewer stars than the usual known larger open clusters.

	TYPE	RA	DEC	MAG	SIZE
STREICHER 86 DSH J0027.5-3517	Asterism	00h27m.30	-35°17'.18	10.5	15'

STREICHER 87 – DSH J0522.4-2540
Lepus



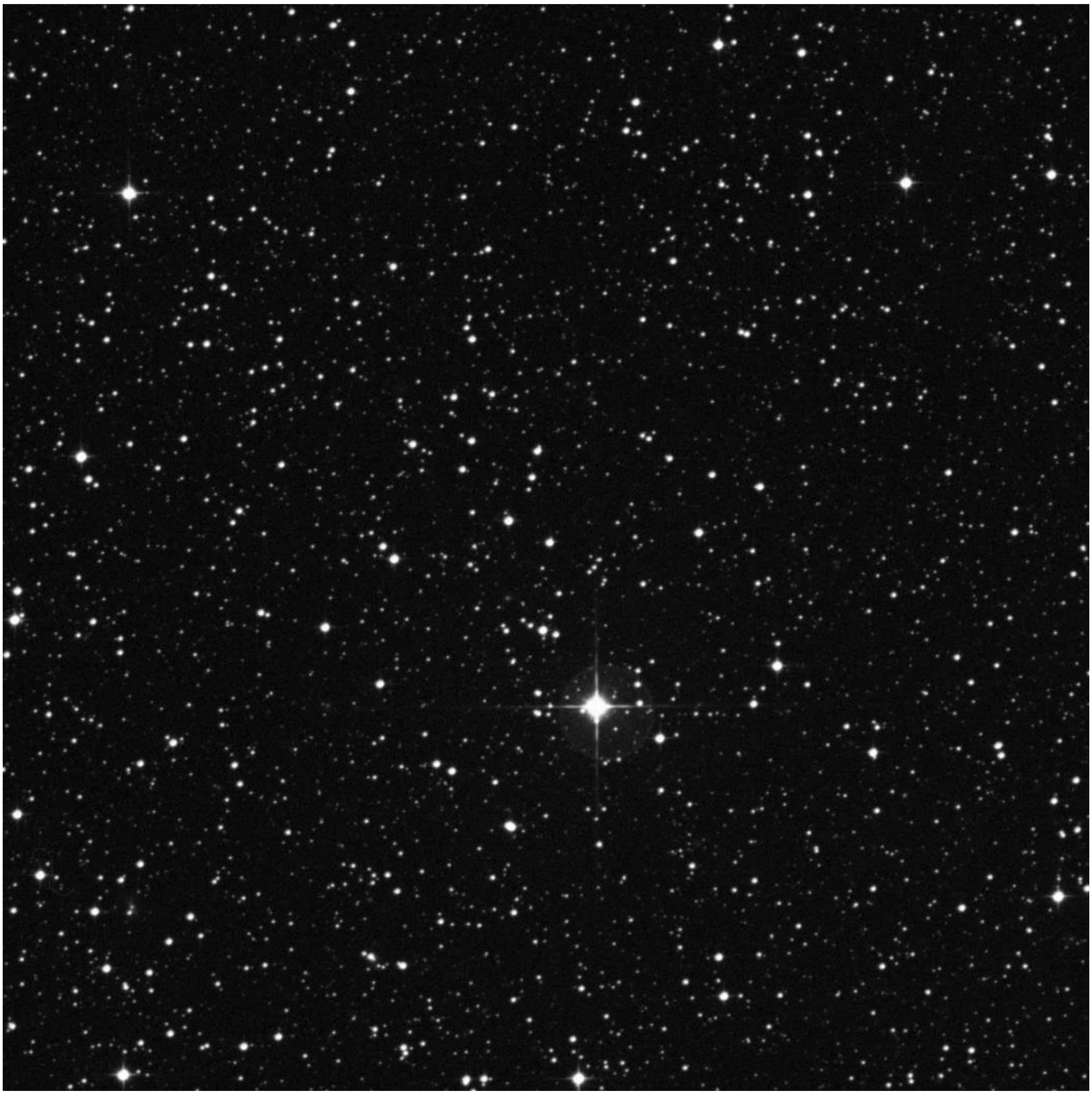
The yellow magnitude 8 star HD 35285 tops this stringy grouping towards the north edge. The other stars curve towards the south much like a type of hood shape. The very tiny edge-on galaxy PGC 17187 is situated in the downward string next to a look-alike double star, as can be seen in the Deep Sky Survey photograph below. Also to be searched out and only half a degree northwest is the galaxy IC 411.

OBJECT	TYPE	RA	DEC	MAG	SIZE
STREICHER 87 DSH J0522.4-2540 Pismis-Moreno 1	Asterism	05h22m.26	-25°40'.54	8.4	13'

STREICHER 88 – DSH J1806.7-5830
Pavo

Immediately north and west of the magnitude 6.8 star HD 164806 are faint star strings clumped together. It might look like a busy star field but it is an eye-catcher through the telescope. With higher power, even fainter stars come to light, sharing the field around the bright star.

OBJECT	TYPE	RA	DEC	MAG	SIZE
STREICHER 81 DSH J1806.7-5830	Asterism	18h06m.42	-58°30'.36	10.5	15'



STREICHER 89 – DSH J0450.9+0741
Orion

The constellation of Orion never ceases to impress me with its wonderful objects to search out and enjoy. In the western part of the Orion constellation the magnitude 3 star pi Orionis, also known by the unusual name Tabit, points the way a degree north to this unique two starry triangles. The eastern three stars are less concentrated, with the brighter star between a fainter and closer triangle of similar magnitude stars. This combination is a delight and, to cap it, quite outstanding.

OBJECT	TYPE	RA	DEC	MAG	SIZE
STREICHER 89 DSH J0450.9+0741	**Asterism**	**04h50m.57**	**+07°41'.55**	**8.5**	**7'**

STREICHER 90 – DSH J0636.9+2410
Gemini

In the constellation Gemini, another jewel situated about 2° south-west of the lovely yellow-coloured 2.9 magnitude epsilon Geminorum. A handful of faint stars string along east-west with similar magnitude 12 stars, with the slightly brighter star HD 46865 at the western end. The very faint planetary nebula PK 189.8+07.7 can be spotted 10' south in the photograph below situated left and next to a bright star.

OBJECT	TYPE	RA	DEC	MAG	SIZE
STREICHER 90 DSH J0636.9+2410	Asterism	06h36m.56	+24°10'.30	12	6'

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, the annual *Sky Guide Africa South* and *Nightfall*.

Membership: Membership of the Society is open to all. Potential members should consult the Society's web page : http://assa.saao.ac.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, Hermanus, Johannesburg, Pretoria and the Garden Route Centre; membership of any of these Centres automatically confers membership of the Society.

Internet contact details: email: assa@saao.ac.za Home Page: http://assa.saao.ac.za

ASSA Council	
President	Dr Daniel Cunnama
Vice-President (outgoing)	Chris Stewart
Vice President (Incoming)	Dr Pierre de Villiers
Membership Secretary	Eddie Nijeboer
Treasurer	AJ Nel
Secretary	Lerika Cross
Council Member	Case Rijsdijk
Council Member	Dr Ian Glass
Bloemfontein Chair	Thinus van der Merwe
Cape Chair	Christian Hettlage
Durban Chair	Amith Rajpal
Garden Route Chair	Case Rijsdijk
Hermanus Chair	Derek Duckitt
Johannesburg Chair	Carmel Ives
Pretoria Chair	Johan Smit
Council Appointees	
Scholarships	Claire Flanagan
ASSA Communication Coordinator	Dr Sally MacFarlane
Webmaster	John Gill
Section Directors	
Dark Sky	Dr Daniel Cunnama
Observing section	Angus Burns
Photometry, Spectroscopy	David Blane (caretaker role)
Cosmology, Astrophysics	Bruce Dickson
History	Chris de Coning
Double and Variable Stars	Dave Blane
Imaging	Martin Heigan
Instrumentation and ATM	Chris Stewart
Comet, Asteroid and Meteor Section	Tim Cooper

ISSN 0024-8266

mnassa

monthly notes of the astronomical society of southern africa

Volume 81 Nos 7-8 **August 2022**

CONTENTS