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mnassa
monthly notes of the astronomical society of southern africa
Volume 78 Nos 9 & 10 October 2019

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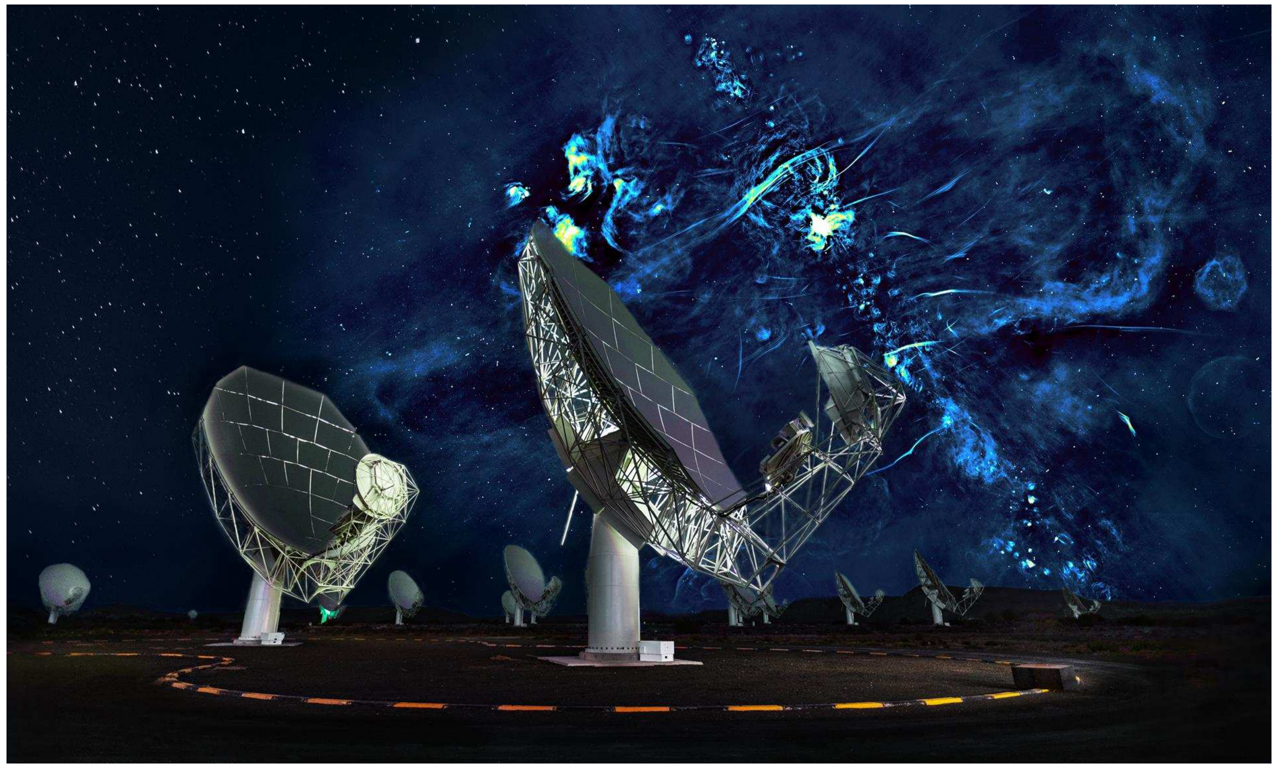

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South Africa's MeerKAT discovers giant radio bubbles at centre of Milky Way; see article page 139.

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

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

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South Africa's HIRAX telescope driving industry engagements

The Hydrogen and Real-time Analysis eXperiment (HIRAX), led out of the University of KwaZulu-Natal (UKZN), has deployed two new prototype telescope dish designs, one aluminium and the other fibreglass, at the South African Radio Astronomy Observatory (SARAO) Hartebeesthoek in Gauteng.

The fibreglass dish was designed and manufactured by MMS Technology in Pretoria, and the aluminium dish was designed and manufactured through a partnership between NJV Consulting and Rebcon in Durban. Funding for the HIRAX prototype dishes was provided by the UKZN and the Department of Science and Innovation through the National Research Foundation.

This milestone marks the successful completion of months of collaboration between the HIRAX project and local engineering and manufacturing firms bringing HIRAX one step closer to the installation of the full 1024-dish array in a compact configuration on the HIRAX main site in the Karoo.

This telescope will enable research into the evolution of dark energy through hydrogen intensity mapping and research on transient radio sources such as fast radio bursts (FRBs) and pulsars. Dark energy is a mysterious force that scientists believe is acting against gravity to cause an accelerated expansion of the Universe. FRBs are mysterious millisecond extragalactic flashes in the sky of unknown origin.

Collaboration on the dish design started in the beginning of 2018 with the purpose of defining final dish requirements for the project. The design of these 6-metre dishes has strict tolerances on the shape, surface accuracy, and receiver position. The mechanical design also allows for the manual repointing of the dishes every few months, enabling the instrument to map about a third of the sky over a five-year period while minimising cost by eliminating the need for active drive mechanisms.

Fig 1. Kavilan Moodley alongside the newly installed MMS prototype dish at the SARAO Hartebeesthoek site.

HIRAX will instrument and analyse the two new prototype dishes over the next few months to develop the final requirements for an open tender for the first 256 dishes to be installed at the HIRAX main site in the Karoo.

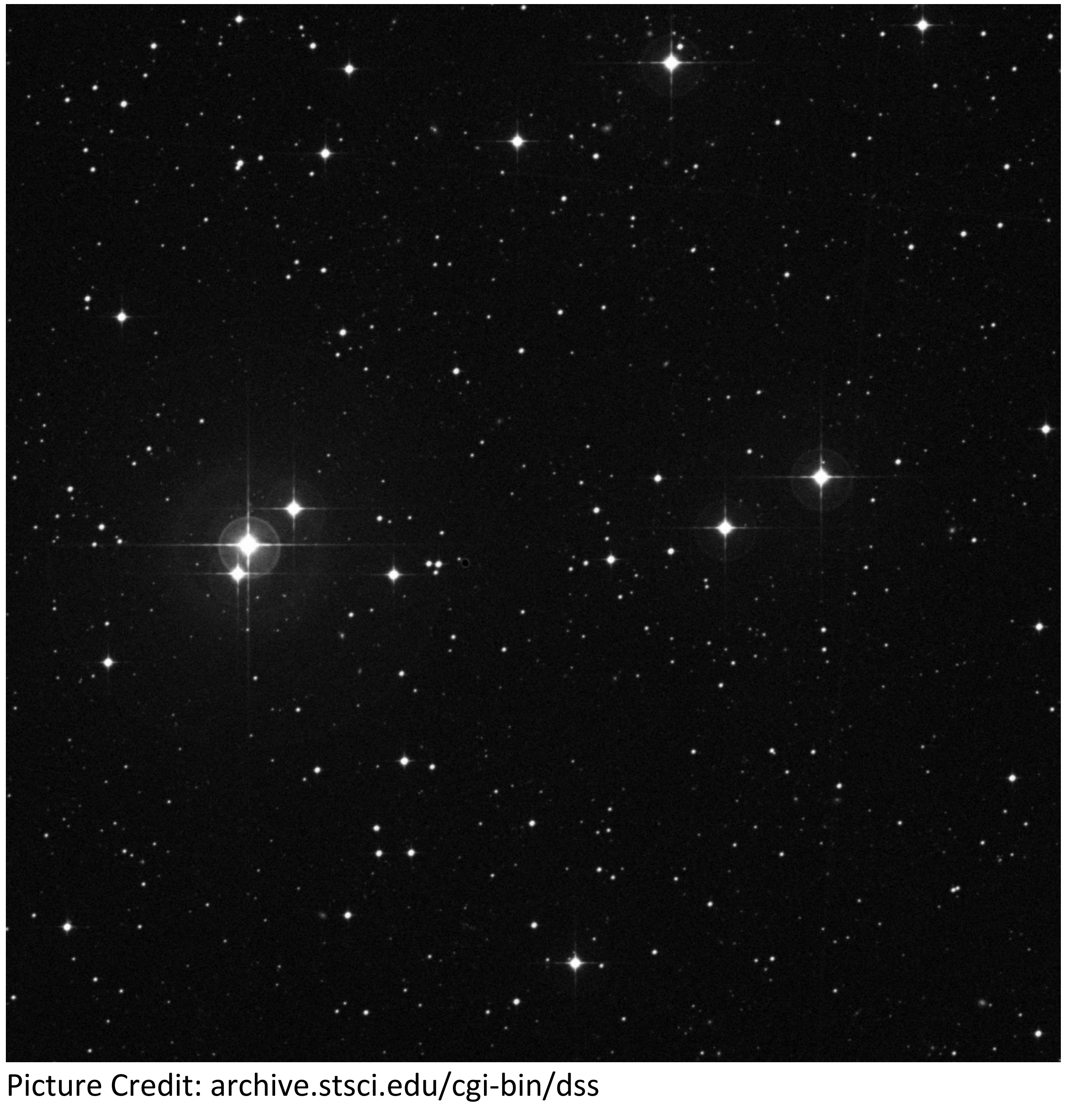
SARAO Managing Director Rob Adam said: “After the successful testing at our Hartebeesthoek site we are looking forward to hosting HIRAX at our site in the Karoo. We always had the idea that the SKA site would prove to be an attractor for other leading-edge global astronomy projects and this is turning out to be the case.”

This installation could not have been achieved without the support of the professional staff at the SARAO Hartebeesthoek site. In this context the experience and domain knowledge of SARAO staff have been harnessed to provide support and technical assistance for various aspects of the HIRAX project. All of the current antenna prototyping work is being conducted at the SARAO Hartebeesthoek Observatory site, and SARAO staff at the site have assisted with the installation and testing of the dishes as well as the execution of the associated civil infrastructure work.

Streicher 17 - Caelum

While observing the galaxy NGC 1687 in the constellation Caelum, my attention was attracted by a string of stars approximately 18’ to the south. This half-moon string shows off three brilliant stars towards the eastern side, with the brightest star 6.8 magnitude. The centre comprises of only fainter stars, with slightly brighter stars to the western tail end.

OBJECT	TYPE	RA	DEC	MAG	SIZE
Streicher 17 DSH J0451.2-3414	Asterism	04h51’m15”	-77°20’.48”	6.8	17’



Picture Credit: archive.stsci.edu/cgi-bin/dss

Streicher 16 - Ara

While observing NGC 6208 I noticed a small grouping of stars situated approximately 17' to the west of the open cluster. Seven stars stand out strongly against the background star field. An off-white colour 8.2 magnitude star takes the lead with a few 11 magnitude stars that is situated to the west. The centre of this group is enveloped by two components that appear double. It resembles a type of pram or pushcart.

OBJECT	TYPE	RA	DEC	MAG	SIZE
Streicher 16 DSH J1734.6-4835	Asterism	16h47'm.32"	-53°40'.42"	11	4.8'

Picture Credit: archive.stsci.edu/cgi-bin/dss

Cynthia Chiang, HIRAX Instrumentation Lead and Professor at McGill University and Fractional Professor at UKZN, said: "In order to deliver high-precision science, HIRAX has stringent specifications that require custom-built telescope dishes. The two new dishes from MMS and Rebcon represent a significant milestone toward achieving HIRAX's goals, and it will be crucial for informing the final instrument design." Both MMS and the NJV/Rebcon collaboration worked hand-in-hand with the HIRAX project to produce prototype designs that will inform final dish requirements for the HIRAX project.

Fig 2. The 10-dish HIRAX prototype array in the foreground featuring the newly installed NJV Consulting/Rebcon dish at front and centre. The 26m dish at the SARAO Hartebeesthoek site is visible in the background.

The MMS dish was installed in August 2019 by the team led by MMS Director Heinrich Bauermeister and consists of a fine aluminium mesh embedded in fibreglass. The MMS dish can tilt in elevation 30 degrees either side of zenith. "Designing and manufacturing this dish was a serious trade-off between performance and cost. For this reason, the mount was kept as low and simple as possible and the dish itself as thin as possible without compromising too much on performance. The single piece composite material dish does not need any post-manufacturing setup, and the mount is low enough to facilitate easy adjustment of the dish elevation by one person," said Bauermeister.

The NJV/Rebcon dish was installed in October 2019 by the team led by Warren Butler, who indicated that "team input of the design development was dynamic to incorporate practical solutions regarding assembly/disassembly, transportation, ease of installation on site in a remote location and serviceability of the prototype once installed".

"The design intent was realised by a form of laser-cut profiled aluminium elements which provided the parabolic accuracy the project required. The appropriate skills and collaboration have resulted in a practical buildable and easily erectable structure, that is fully recyclable," he added.

The dish is made of aluminium mesh with an aluminium backing structure. Furthermore, it is fixed in azimuth and can tilt in elevation down to the horizon. Of the collaboration between the HIRAX project and NJV Consulting/Rebcon, Linda Ness, Director of NJV Consulting (Pty) Ltd asserted: "Collaboration between designer and fabricator on unusual engineering fabrications at conceptual stage is invaluable, and this was one of those great opportunities. Early interaction like this allows cross-over of skills between the two companies, who have worked together for many years. With multiple units in mind, material optimisation, repeat fabrication and erection are key. Detailed structural modelling analyses and finer stress design work could then be downstream from wholly considered upfront thinking, sketching and deliberation together with the scientists."

The HIRAX team hopes that these partnerships are the first of many to come between the project and South African industry. In addition to collaborating on HIRAX dish hardware, the project hopes to manufacture some of its subsystems in South Africa, work with local technology companies to develop big data analysis tools, and hire local labour for the deployment of the instrument in the Karoo.

Kavilan Moodley, Principal Investigator of the project and Professor at UKZN, emphasised: "Through these and future collaborations with industry and the scientific community, the project endeavours to build technical capacity nationally as South Africa increases its radio astronomy portfolio through MeerKAT and the development towards the Square Kilometre Array (SKA)."

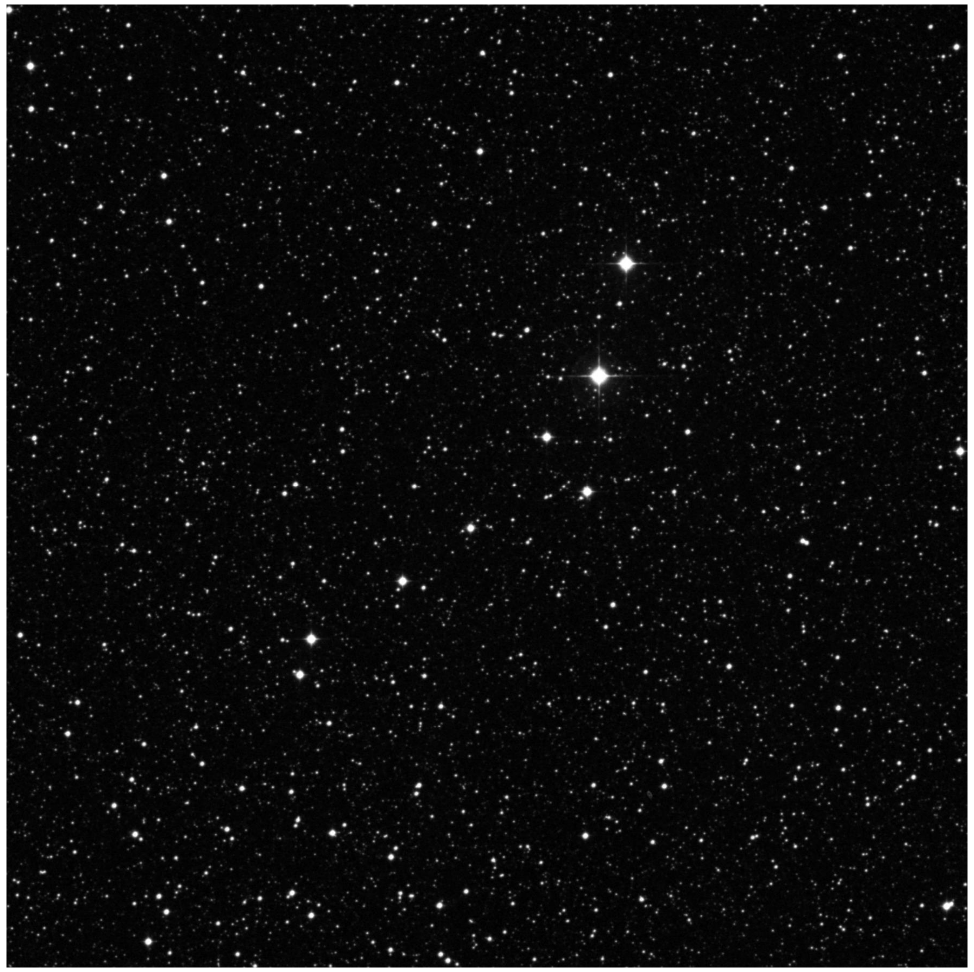
(NRF Press Release)

Streicher 15 - Ara

Streicher 15 - Ara

This asterism is special because it was one of the very first grouping when searching for asterisms. Eight stars in a half-moon string, with an average brightness of approximately 7-8 magnitude quite loose from one another. Standing well out of a relatively faint star-field although stars of fainter than approximately 10 magnitude and fainter. The brightest star 6.3 appears light yellow in colour and visible to the north of the string that snakes south-east. The faintest star 9.5 magnitude is towards the middle section, with a visual double, ending off this string to the south. Star strings may resemble different shapes and this grouping in the constellation Ara resembles to me a group of swallows in flight.

OBJECT	TYPE	RA	DEC	MAG	SIZE
Streicher 15 DSH J1734.6-4835	Asterism	17h34'm.38"	-48°35'.00"	9	17'

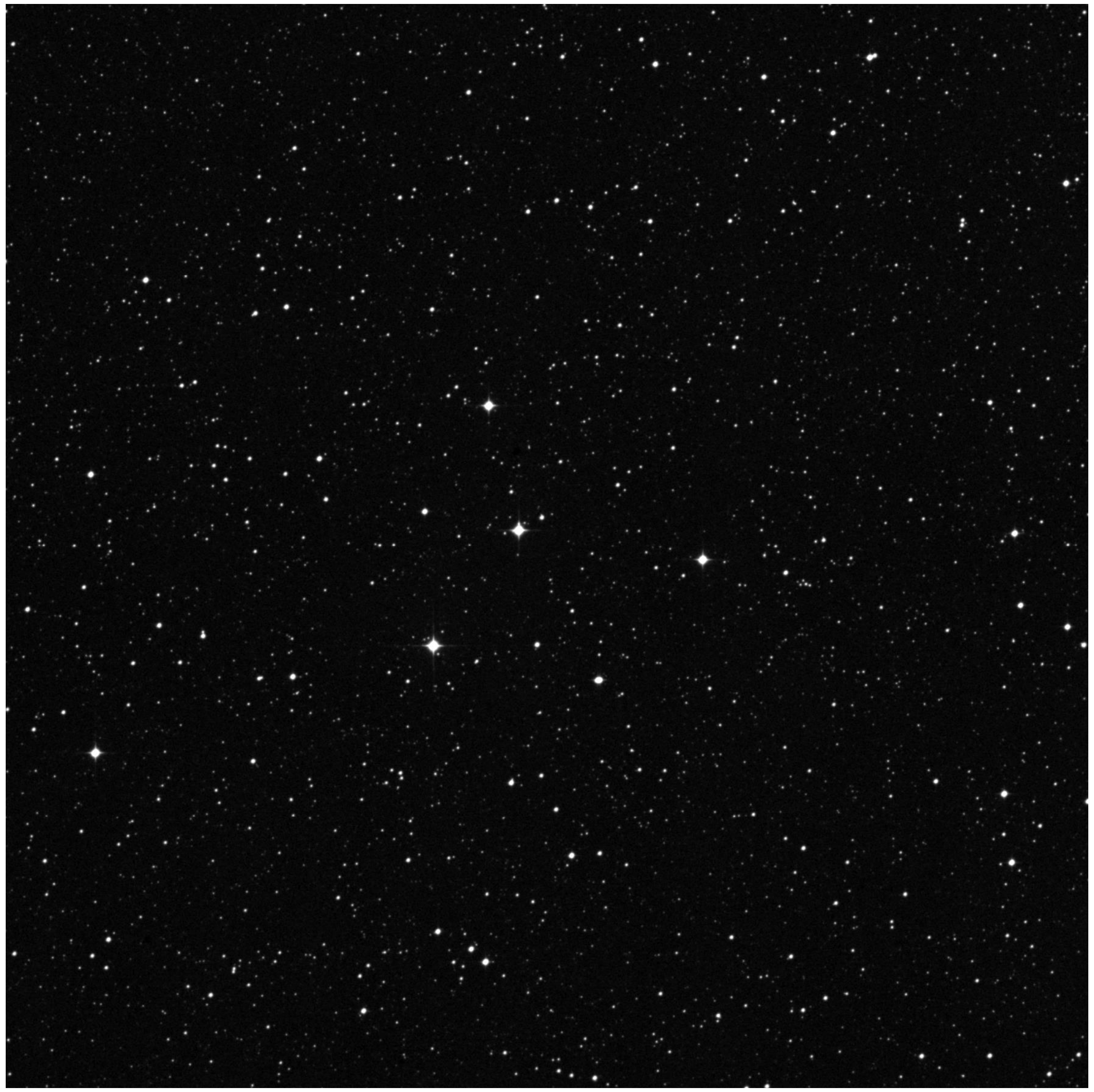


Picture Credit: archive.stsci.edu/cgi-bin/dss

Streicher 14 - Apus

What makes these five stars remarkable is the fact that it forms a clear symmetrical triangle with the magnitude 8 yellow star in the centre. This arrow shape is approximately 10.9’ in size with a distant of 7’ from each other. A handful of stars show up as double in the field of view.

OBJECT	TYPE	RA	DEC	MAG	SIZE
Streicher 14 DSH J1457.1-7120	Asterism	14h57’m.10”	-71°20’.54”	10.9	9’



Picture Credit: archive.stsci.edu/cgi-bin/dss

News Note: 80th Birthday of George Ellis

On 21 October 2019 a day of lectures was held to celebrate the 80th birthday of Prof George Ellis, the noted South African Cosmologist who has had a major influence on South African science and is the founder of the South African school of cosmology.

Most of the nine people who lectured were former students or colleagues of Ellis who remain active in Cosmology.

George Ellis has had a wide range of interests apart from cosmology itself. The first item on the programme was a summary of his career, presented by one of his most academically successful former students, Roy Maartens of UWC. The other presenters were Charles Hellaby, Julien Larena, Ritu Goswami, Amanda Weltman, Jeff Murugan, Leen Remmelzwaal and George himself. The last two lectures were concerned with processes in the brain, one of his most recent interests.

News Note: SALT Annual Report for 2018

Annual Reports from observatories are valuable in that they give a more comprehensive overview of activities than the ephemeral snippets that appear in press releases or on web sites. They were a feature of the former Royal Observatory that was carried on by SAAO but unfortunately they came to an end about 2001. Understandably, they are not trivial to produce but they do provide a historical record of achievements that has long-term value.

Fortunately, Annual Reports are once again being published by SALT and SAAO. That for the Southern African Large Telescope (SALT) has just appeared, edited by Anja Schröder. Its various sections include one on the institutional members of the SALT Foundation, which is an international rather than a national venture, managed contractually by SAAO. South Africa in fact has only about 1/3 of the investment, the other current partners being the University of Wisconsin, Rutgers University, a Polish consortium, Dartmouth College, IUCAA (India), a UK consortium, the University of North Carolina and the American Museum of natural History. Representatives from each institution as well as the South African National Research Foundation constitute a Board of Directors.

The new report includes some of the science highlights. As might be expected, a large telescope like SALT is used for studying faint objects and time is given out for observations in exciting and new fields, ranging from Solar System objects to QSOs.. Most of the 45 astronomical research papers that were produced are the fruits of international collaborations between partner institutions.

A large proportion of the Observatory's effort now goes into the development of new equipment and the "Technical Operations" group is a major part of present-day SALT, with construction of new instruments and frequent updates to older ones a significant proportion of the Observatory's activity. A large telescope usually requires large and complicated accessory instruments. Everything is on a larger scale than in previous times. The design and use of each accessory is complicated and more pressure is placed on the technical staffs.

Outreach and Education are large parts of the Observatory's work compared to earlier times when there was not so much pressure to be answerable to society. For example, job shadowing has become very important, especially in the last four years, when 101 school pupils went through the programme.

A most interesting booklet "Africa's Giant Eye Explores the Universe" has also been published recently, with emphasis on the recent scientific projects at SALT. An Annual Report for SAAO is also in preparation and should be available shortly. Copies of these publications should be available from SALT and SAAO.

News Note: SAAO/MeerKAT confirmation of flaring black hole

Researchers from the South African Astronomical Observatory (SAAO) have utilised the South African Radio Astronomy Observatory MeerKAT Telescope to confirm the existence of a never-before-seen flaring black hole.

The European Space Agency's (ESA) XMM-Newton X-Ray space telescope recently discovered mysterious X-ray flashes from the active black hole at the core of the galaxy GSN 069, some 250 million light-years away.

On 24 December 2018, the object was seen to suddenly increase its brightness by up to a hundred times. It dimmed back to its normal levels within one hour and lit up again nine hours later.

"It was completely unexpected," says Giovanni Miniutti, of the Centro de Astrobiología in Madrid, Spain, lead author of a new paper published in the journal, *Nature,* today.

"Giant black holes regularly flicker like a candle but the rapid, repeating changes seen in GSN 069 from December onwards are something completely new."

"The X-ray emission comes from material that is being accreted into the black hole and heats up in the process," explains Giovanni.

Streicher Asterisms 13-17

Streicher 13 - Apus

This grouping of stars is wide spread but standing out relatively good against the background star field. Somewhat oblong north-south of which the brightest stars situate to the north. Fainter stars complete this grouping and resembles perhaps a bird with its wings open in flight. The asterism is situated 2 degrees west of beta Apodis.

OBJECT	TYPE	RA	DEC	MAG	SIZE
Streicher 13 DSH J1607.4-7720	Asterism	16h07'm.25"	-77°20'.48"	9.7	20'

Picture Credit: archive.stsci.edu/cgi-bin/dss

Conclusion

Although not the authors primary field of interest (high resolution planetary imaging), this was an exciting and scientifically valuable project, which, thanks to the team effort, appears to have been successful. A formal paper will be produced in coming months, with all team members being included as co-authors.

This is a further confirmation that amateurs, with suitable equipment, dedication, a willingness to learn can make a serious scientific contribution. Anyone who is interested in such projects and may want to be included in potential future events is welcome to contact the author at clyde@icon.co.za

Although never before observed, Giovanni and colleagues think periodic flares like these might actually be quite common in the Universe. It is possible that the phenomenon hadn't been identified before because most black holes at the cores of distant galaxies, with masses millions to billions of times the mass of our Sun, are much larger than the one in GSN 069, which "weighs" about 400,000 times our Sun.

In order to study the radio properties of the source of these X-ray flashes, astronomers from the South African Astronomical Observatory (SAAO) used the powerful new capabilities provided by their fellow National Research Foundation (NRF) Facility, the South African Radio Astronomy Observatory (SARAO).

SAAO Astronomer's Dr Retha Pretorius and Dr Itumeleng Monageng utilised SARAO's MeerKAT Radio telescope and were able to detect the black hole at lower frequencies (1.3GHz) to complement other radio observations from ATCA (5.5 and 9 GHz) and VLA (6 GHz).

"Having access to such a powerful radio telescope has enabled us to compete internationally on major discoveries like this, MeerKAT is yet another world-class telescope available to South African astronomers" said Dr Monageng.

SARAO Director Rob Adam added "It's exciting to see MeerKAT being used in a groundbreaking multi-wavelength study by young South African researchers from our sister observatory"

Fig 1. A nighttime view of MeerKAT

News Note: SALT observes super fast spirals!

Astronomers using the Southern African Large Telescope (SALT) have measured the rotation of some of the largest spiral galaxies, spinning at up to 570 kilometres per second!

Their rapid spin is a result of sitting within an extraordinarily massive cloud, or halo, of dark matter – invisible matter detectable only through its gravity. The largest "super spiral" studied here resides in a dark matter halo with mass at least 40 trillion times that of our Sun.

When it comes to galaxies, how fast is fast? The Milky Way, an average spiral galaxy, spins at a speed of 210 kilometres per second in our Sun's neighbourhood. New research has found that the most massive spiral galaxies spin faster than expected. These "super spirals," the largest of which weigh about 20 times more than our Milky Way, spin at a rate of up to 570 kilometres per second.

Super spirals are exceptional in almost every way. In addition to being much more massive than the Milky Way, they're also brighter and larger in physical size. The largest span 450 000 light-years compared to the Milky Way's 100 000-light-year diameter. Only about 100 super spirals are known to date. Super spirals were discovered as an important new class of galaxies while studying data from the Sloan Digital Sky Survey as well as the NASA/IPAC Extragalactic Database (NED).

"Super spirals are extreme by many measures," says Patrick Ogle of the Space Telescope Science Institute in Baltimore, Maryland. "They break the records for rotation speeds."

Ogle is the first author of a paper that was published October 10, 2019, in the Astrophysical Journal Letters. The paper presents new data on the rotation rates of super spirals collected with the Southern African Large Telescope (SALT), the largest single optical telescope in the southern hemisphere. Additional data were obtained using the 5-meter Hale telescope of the Palomar Observatory, operated by the California Institute of Technology. Data from NASA's Wide-field Infrared Survey Explorer (WISE) mission was crucial for measuring the galaxy masses in stars and star formation rates.

"This work beautifully illustrates the powerful synergy between optical and infrared observations of galaxies, revealing stellar motions with SDSS and SALT spectroscopy, and other stellar properties — notably the stellar mass or 'backbone' of the host galaxies — through the WISE mid-infrared imaging," says Tom Jarrett of the University of Cape Town, South Africa.

producing the initial light curve and confirming the acceptability of the quality of the data. He confirmed that the data would be sufficient to provide measurement of the dwarf planet to an accuracy of less than 5km.

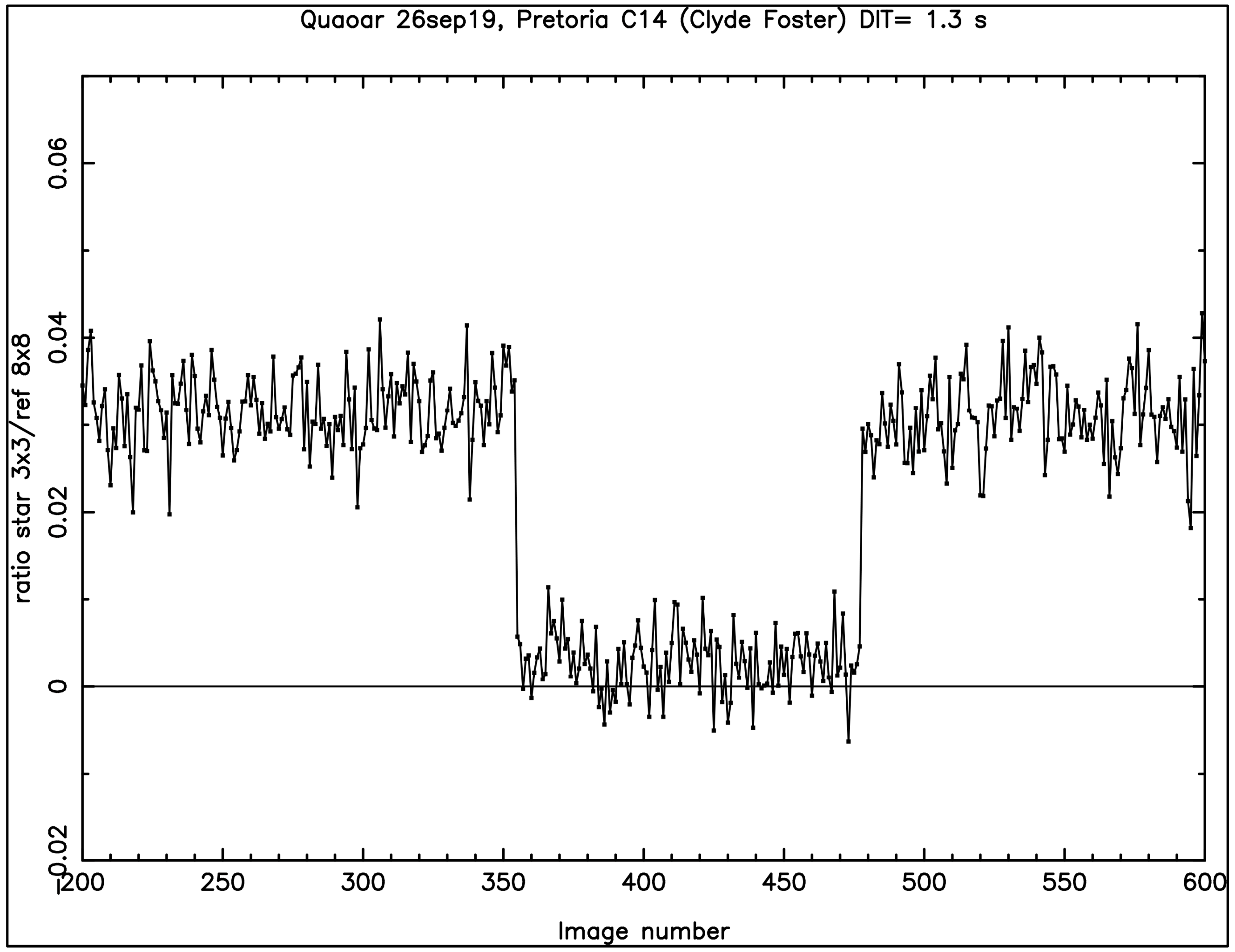


Fig 3. Light curve generated by Bruno Sicardy

Team

Co-ordination and report : Bruno Sicardy and Felipe Braga Ribas (Sorbonne University/Paris Observatory)
Mike Kretlow, 40cm Grootfontein, Namibia. Positive observation
Wolfgang Beisker, 50cm, Hakos/IAS, Namibia. Positive observation
Clyde Foster, 35cm, Centurion, South Africa. Positive observation
Bernard Mondon, La Reunion. Clouded out
Jean-Paul Teng, Les Makes. Clear only for Weywot orbital crossing.

The two evenings prior to the occultation were used to identify the field and occultation star, as well as to test various capture settings. Test images were forwarded to the co-ordinator for comment. Light pollution was an initial concern, although it became evident that capture exposures of 1.0-1.5s would be acceptable, subject to sky and seeing conditions on the night of occultation.

Results

The conditions on the night of occultation were clear, although seeing conditions were not quite as good as the previous evening, when testing was done.

A further test run was done 40 mins prior to the first data run (Weywot) to confirm capture settings, and an exposure of 1.2 secs was selected, which proved to be satisfactory for scientific purposes.

The computer clock was synchronised with a local server approximately 5 mins before start of capture.

The first Data capture run (Weywot) ran from 18h33UT until 18h48UT as the computer clock was resynchronised between the first and second data runs.

The second data capture run (Quaoar) started at 18h57UT and continued until 19h12UT, a duration of 874s and 719 frames were captured

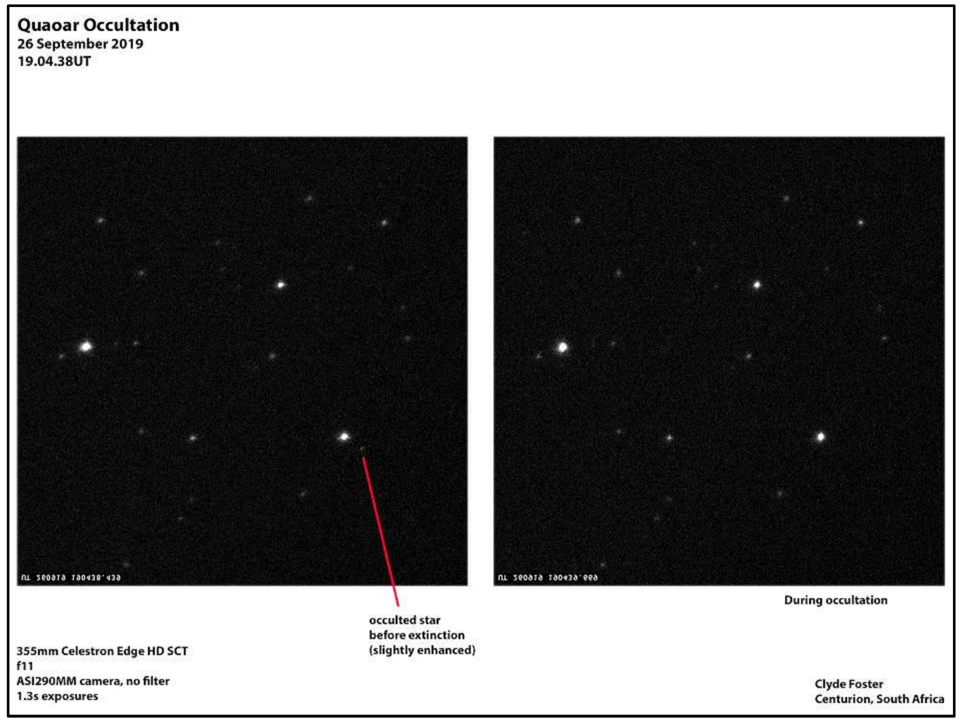


Fig 2. Occultation images

The disappearance and re-appearance of the star were visually observed on screen, which, in itself was an exciting experience.

The captured data was subsequently transferred to Bruno Sicardy via dropbox, and he undertook the initial analysis,

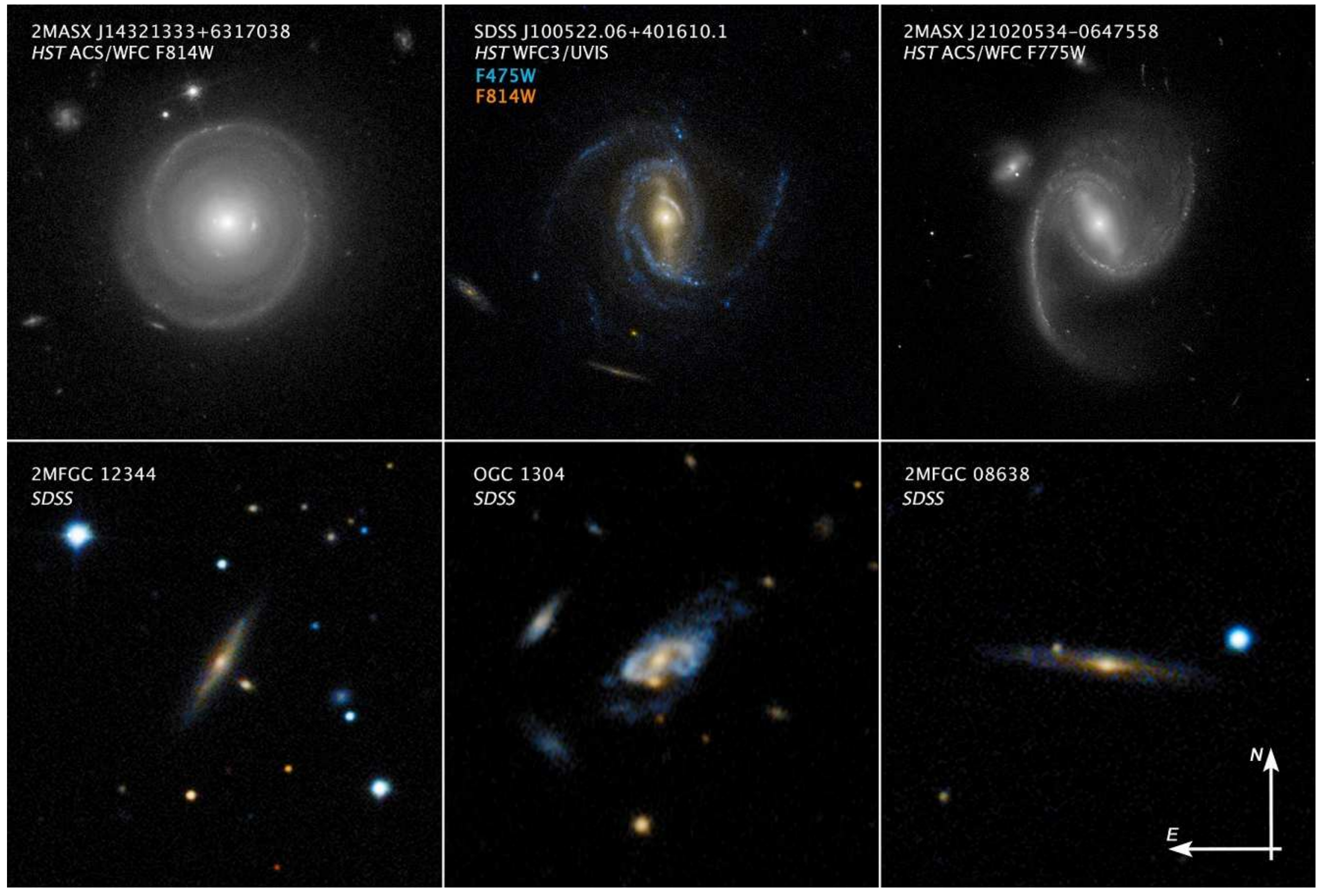


Fig 1. The top row of this mosaic features Hubble images of three spiral galaxies, each of which "weighs" several times as much as the Milky Way. The bottom row shows three even more massive spiral galaxies that qualify as "super spirals," which were observed by the ground-based Sloan Digital Sky Survey. Super spirals typically have 10 to 20 times the mass of the Milky Way. The galaxy at lower right, 2MFGC 08638, is the most massive super spiral known to date, with a dark matter halo weighing at least 40 trillion Suns.

Image Credits: Top row: NASA, ESA, P. Ogle and J. DePasquale (STScI). Bottom row: SDSS, P. Ogle and J. DePasquale (STScI)

Theory suggests that super spirals spin rapidly because they are located within incredibly large clouds, or halos, of dark matter. Dark matter has been linked to galaxy rotation for decades. Astronomer Vera Rubin pioneered work on galaxy rotation rates, showing that spiral galaxies rotate faster than if their gravity were solely due to the constituent stars and gas. An additional, invisible substance known as dark matter must influence galaxy rotation. A spiral galaxy of a given mass in stars is expected to rotate at a certain speed. Ogle's team finds that super spirals significantly exceed the expected rotation rate.

Super spirals also reside in larger than average dark matter halos. The most massive halo that Ogle measured contains enough dark matter to "weigh" at least 40 trillion times as much as our Sun. That amount of dark matter would normally contain a group of galaxies rather than a single galaxy.

"It appears that the spin of a galaxy is set by the mass of its dark matter halo," Ogle explains. The fact that super spirals break the usual relationship between galaxy mass in stars and rotation rate is a new piece of evidence against an alternative theory of gravity known as Modified Newtonian Dynamics, or MOND. MOND proposes that on the largest scales like galaxies and galaxy clusters, gravity is slightly stronger than would be predicted by Newton or Einstein. This would cause the outer regions of a spiral galaxy, for example, to spin faster than otherwise expected based on its mass in stars. MOND is designed to reproduce the standard relationship in spiral rotation rates, therefore it cannot explain outliers like super spirals. The super spiral observations suggest no non-Newtonian dynamics is required.

Despite being the most massive spiral galaxies in the universe, super spirals are actually underweight in stars compared to what would be expected for the amount of dark matter they contain. This suggests that the sheer amount of dark matter inhibits star formation. There are two possible causes: 1) Any additional gas that is pulled into the galaxy crashes together and heats up, preventing it from cooling down and forming stars, or 2) The fast spin of the galaxy makes it harder for gas clouds to collapse against the influence of centrifugal force. "This is the first time we've found spiral galaxies that are as big as they can ever get," Ogle says.

Despite these disruptive influences, super spirals are still able to form stars. Although the largest elliptical galaxies formed all or most of their stars more than 10 billion years ago, super spirals are still forming stars today. They convert about 30 times the mass of the Sun into stars every year, which is normal for a galaxy of that size. By comparison, our Milky Way forms about one solar mass of stars per year.

Ogle and his team have proposed additional observations to help answer key questions about super spirals, including observations designed to better study the motion of gas and stars within their disks. After its 2021 launch, NASA's James Webb Space Telescope could study super spirals at greater distances and correspondingly younger ages to learn how they evolve over time. And NASA's WFIRST mission may help locate more super spirals, which are exceedingly rare, thanks to its large field of view.

The Space Telescope Science Institute is expanding the frontiers of space astronomy by hosting the science operations centre of the Hubble Space Telescope, the science and operations centre for the James Webb Space Telescope, and the science

Fig 1. Bruno Sicardy, the author and Wolfgang Beisker at EPSC-DPS 2019 in Geneva

Occultation

Estimations had provided the following data for Centurion, Gauteng, from where the author would be observing the event:
Star: GAIADR2 4145210002691776000 (G mag 14.5)
Date : 26 September 2019
Estimated time of disappearance: 19h05:30UT
Maximum duration: 151.5 secs

Data captured and analysed from a previous occultation had identified a small moon, Weywot. The co-ordinator therefore requested two sets of data to be captured in order to attempt to capture any data for the moon, as well the main event: From 18h33 to 18h48UT (Weywot) and from 19h00 to 19h10UT(Quaoar).

The following equipment was used:

- Telescope: Permanently mounted Celestron 14" f/11 Edge HD SCT.
- No Barlow or focal reducer(native f/11)
- No filter
- No binning
- Camera: ZWO ASI290MM (mono)
- Capture software: Firecapture

rotational acceleration of asteroid (101955) Bennu from OSIRIS-REx observations, Nature Communications 10, 1291.

Lunsford R. (2019a) *Meteor Activity Outlook for 21-27 September 2019*, posted on IMO-News on 2019 September 20.

Lunsford R. (2019b), private communication by email dated 8 October 2019.

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Ye Q. (2019), *Prediction of Meteor Activities from (101955) Bennu*, Res. Notes AAS, 3, 56.

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Dwarf Planet Quaoar Occultation event

Clyde Foster-ASSA Shallow Sky Section Director

Introduction

Whilst attending EPSC-DPS in Geneva, Switzerland in September this year, the author was informed of an imminent occultation of a 14th magnitude star by the Dwarf Planet Quaoar, a Trans-Neptunian Object (TNO) orbiting the sun in the Kuiper belt, and which would be observable from the author's home location. Estimated to be 1 150 km in diameter, at the time of occultation Quaoar would be approximately 6.3 billion kms distant from Earth. Too faint be to observed directly other than by Hubble and other large professional telescopes (even then it is just resolved as non-stellar), rare occultation events, where the dwarf planet moves in front of a distant star, cutting off its light for a short period, provide valuable scientific information regarding the object, such as size, speed, shape, exact position etc. A team was put together from observers in Namibia, South Africa and Reunion, co-ordinated by Bruno Sicardy of Sorbonne University and Paris Observatory.

operations centre for the future Wide Field Infrared Survey Telescope (WFIRST). STScI also houses the Mikulski Archive for Space Telescopes (MAST) which is a NASA-funded project to support and provide to the astronomical community a variety of astronomical data archives and is the data repository for the Hubble, Webb, Kepler, K2, TESS missions and more.

News Note: MeerKAT discovers giant radio bubbles at centre of Milky Way

An international team of astronomers using the MeerKAT telescope has discovered enormous balloon-like structures that tower hundreds of light-years above and below the centre of our galaxy. Caused by a phenomenally energetic burst that erupted near the Milky Way's supermassive black hole a few million years ago, the MeerKAT radio bubbles are shedding light on long-standing galactic mysteries.

"The centre of our galaxy is calm when compared to other galaxies with very active central black holes," said Ian Heywood of the University of Oxford and lead author of an article appearing in the journal *Nature* today. "Even so, the Milky Way's central black hole can – from time to time – become uncharacteristically active, flaring up as it periodically devours massive clumps of dust and gas. It's possible that one such feeding frenzy triggered powerful outbursts that inflated this previously unseen feature."

Using the South African Radio Astronomy Observatory (SARAO) MeerKAT telescope, Heywood and his colleagues mapped out broad regions in the centre of the galaxy, conducting observations at wavelengths near 23 centimeters. Radio emission of this kind is generated in a process known as synchrotron radiation, in which electrons moving at close to the speed of light interact with powerful magnetic fields. This produces a characteristic radio signal that can be used to trace energetic regions in space. The radio light seen by MeerKAT easily penetrates the dense clouds of dust that block visible light from the centre of the galaxy.

Fig 1 shows a radio image of the centre of the Milky Way with a portion of the MeerKAT telescope array in the foreground. The plane of the galaxy is marked by a series of bright features, exploded stars and regions where new stars are being born, and runs diagonally across the image from lower right to top centre. The black hole at the centre of the Milky Way is hidden in the brightest of these extended regions. The radio bubbles extend from between the two nearest antennas to the upper right corner. Many magnetised filaments can be seen running parallel to the bubbles. In this composite view, the sky to the left of the second nearest antenna is the night sky visible to the unaided eye, and the radio image to the right has been enlarged to highlight its fine features.

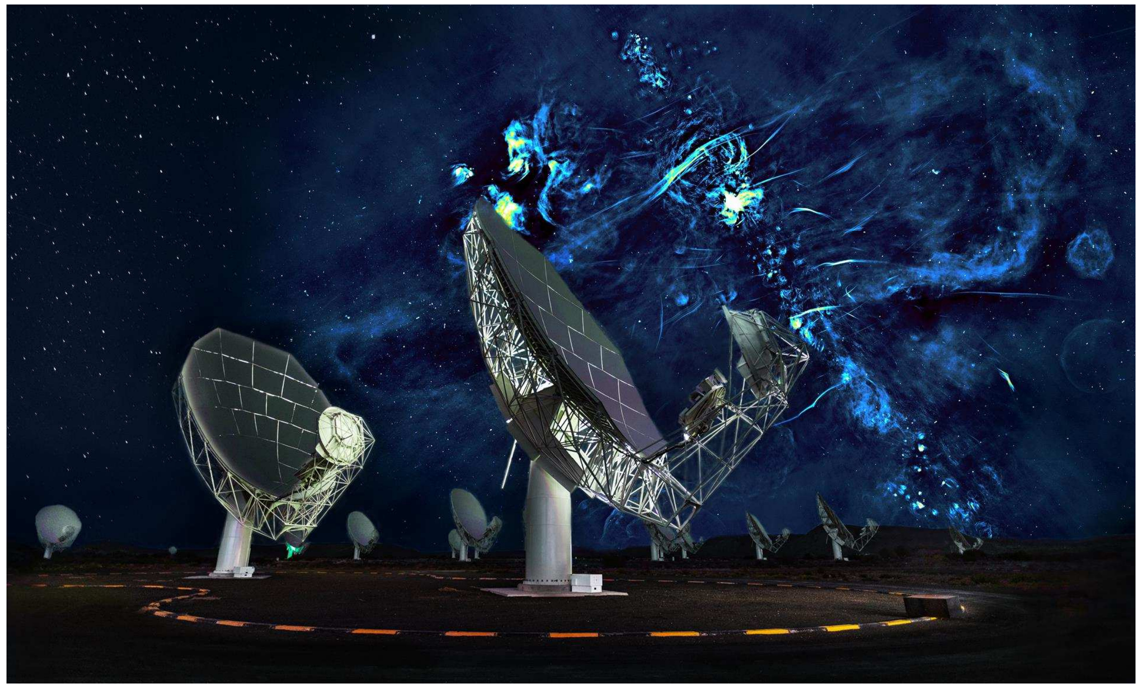

Fig 1. A composite of the radio bubbles and the MeerKAT telescope.

By examining the nearly identical extent and morphology of the twin bubbles, the researchers think they have found convincing evidence that these features were formed from a violent eruption that over a short period of time punched through the interstellar medium in opposite directions. "The shape and symmetry of what we have observed strongly suggest that a staggeringly powerful event happened a few million years ago very near our galaxy's central black hole," said William Cotton, an astronomer with the US National Radio Astronomy Observatory and a co-author on the paper. "This eruption was possibly triggered by vast amounts of interstellar gas falling in on the black hole, or a massive burst of star formation which sent shockwaves careening through the galactic centre. In effect, this inflated bubbles in the hot, ionised gas near the galactic centre, energising it and generating radio waves that we eventually detect here on Earth."

The environment surrounding the central black hole is vastly different than elsewhere in the Milky Way, and is a region of many mysteries. Among those are very long (tens of light-years) and narrow radio filaments found nowhere else, the origin of which has remained an unsolved puzzle since their discovery 35 years ago.

"The radio bubbles discovered by MeerKAT now shed light on the origin of the filaments," said Farhad Yusef-Zadeh at Northwestern University in the USA, and a co-author of the paper. "Almost all of the more than 100 filaments are confined by the

–47.8° to 19h26m, –49.8°. Path length 49.1°, duration 3 seconds, giving apparent speed 16.4 °/sec. First third of passage white, then yellow as the meteor became brighter, last 25% orange core surrounded by white with sparkling appearance, not dissimilar to the typical Geminid in appearance. Left very persistent white train, lasting for more than 15 seconds. During plotting the path of the fireball the sky suddenly became hazy then quickly cloudy, which was thick and persisted until after dawn.

Conclusions

Any visual activity from the predicted meteor stream from asteroid Bennu and radiating from 00h20 (005°), –34° was barely perceptible in 2019, perhaps exceeding the sporadic background briefly on the night of 24/25 September. Activity was noted from a possible radiant nearby, determined to be around RA = 23h54 (358.5°), Dec. = –29.4° and close to delta Sculptoris with eight members plotted on the night of 25/26 September, including five observed in the half hour interval from 18h56-19h26. A number of meteors were noted from two possible centres around 01h26 (21.5°), +06° and 01h50 (27.5°), –05°, but in both cases the activity was weak. Several meteors were recorded as NTA (3), STA (3) and SPE (2), and 71 meteors were logged as sporadic, which could not be definitely associated with any established radiant.

Acknowledgements

The author would like to thank Magda Streicher for her wonderful hospitality and the use of her dark sky location from where the observations were made, and Bob Lunsford (General Secretary, International Meteor Organization) for comments made during preparation of these results. Figure 1 was adapted from Stellarium version 0.13.0, all credit to the Stellarium Developers.

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RAD2 at 01h26 (21.5°), +06°, located in Pisces with the following coincidences:

22/23 September	21h20	mag 3	med	plot 10
22/23 September	21h41	mag 3	med	plot 12
23/24 September	20h56	mag 3.5	med	plot 42
25/26 September	23h17	mag 4	med	plot 81
25/26 September	23h29	mag 2	fast	plot 83
25/26 September	23h31	mag 4	fast	plot 84

Note that plots 83 and 84 were both fast, and separated by two only minutes in appearance time. However, Bob Lunsford (2019b) points out that any meteors from this location would not be perceived as fast, and must have originated further north, so their appearance so close together in time and aligned with RAD2 was probably coincidental.

RAD3 at 01h50 (27.5°), –05°, located in Cetus, with the following coincidences:

22/23 September	21h20	mag 3	med	plot 10
22/23 September	21h41	mag 3	med	plot 12
24/25 September	22h13	mag 6	med	plot 50
25/25 September	23h17	mag 4	med	plot 81

Note this centre is 12° west of the upsilon Cetid radiant (UCE).

Meteors from the September epsilon Perseid radiant, SPE = 2

Two meteors were recorded as SPE as follows:

23/24 September 19h34 mag 3 med no plot

Peripheral vision behind me, long path left to right from Aries, through Pisces and Capricornus.

24/25 September 21h49 mag –2 fast Plot 44

Long path, bright meteor, mag –2, left 2 second train.

Note the speed of the two meteors were different, and with medium speed the first may better be described as sporadic.

Fireball on 24 September

The highlight of the observations was certainly the bright fireball observed on 24 September at 22h39. Mag –5 at termination. Plot 54, long path from 00h41m,

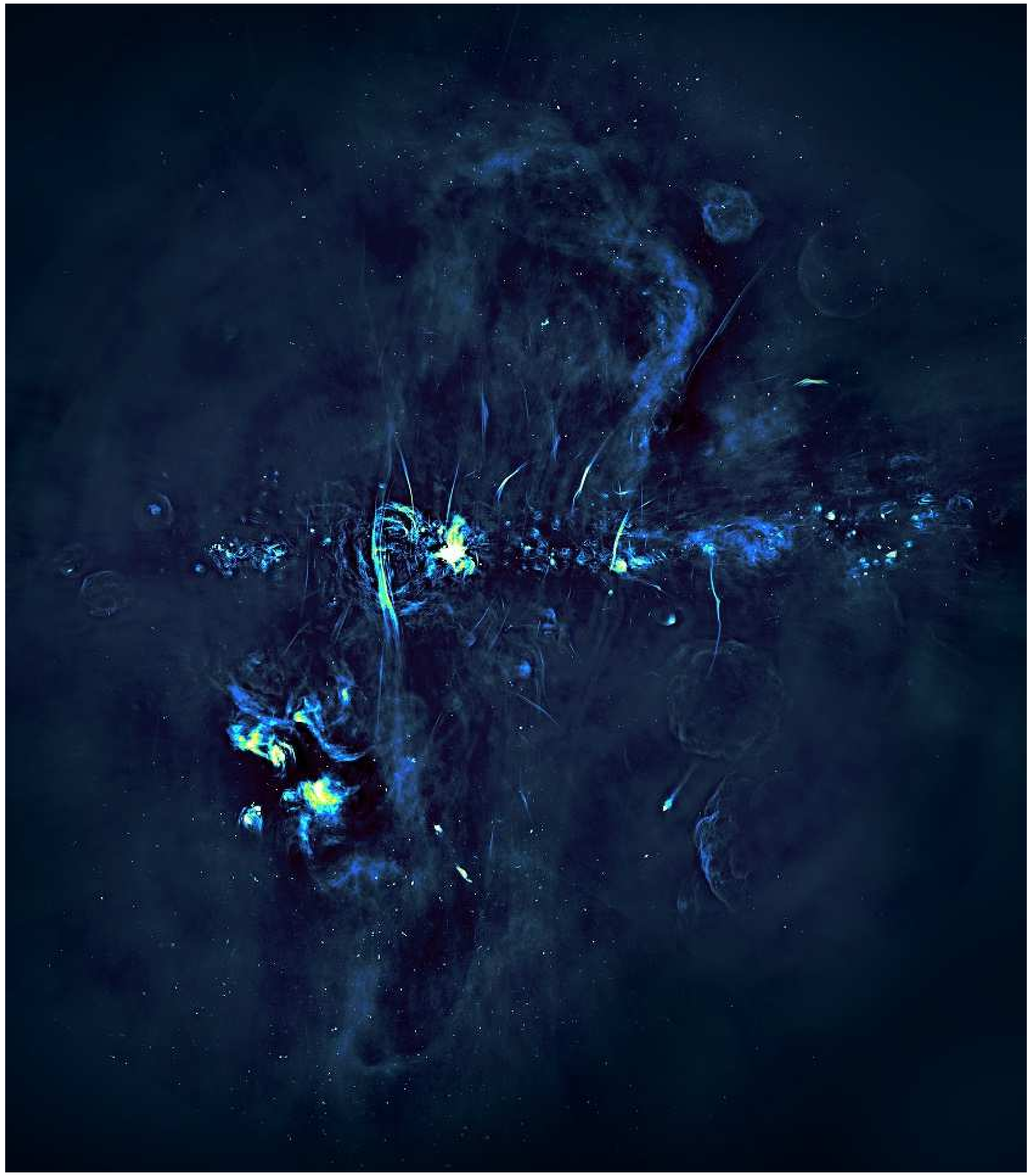

Fig 2. A radio image of the central portions of the Milky Way galaxy showing radio bubbles, observed with the MeerKAT telescope. The plane of the galaxy is marked by a series of bright features, corresponding to exploded stars and regions where new stars are being born, and runs horizontally through the image. The black hole at the centre of the Milky Way is hidden in the brightest of these extended regions. The radio bubbles discovered by MeerKAT extend vertically above and below the plane of the galaxy. Many magnetised filaments can be seen running parallel to the bubbles. (Adapted from results published in Heywood et al. 2019.).

radio bubbles. "The authors suggest that the close association of the filaments with the bubbles implies that the energetic event that created the radio bubbles is also responsible for accelerating the electrons required to produce the radio emission from the magnetised filaments. "These enormous bubbles have until now been hidden by the glare of extremely bright radio emission from the centre of the galaxy," said Fernando Camilo of SARAO in Cape Town, and a co-author on the paper. "Teasing out the bubbles from the background noise was a technical tour de force, only made possible by MeerKAT's unique characteristics and ideal location," according to Camilo. "With this discovery, we're witnessing in the Milky Way a novel manifestation of galaxy-scale outflows of matter and energy, ultimately governed by the central black hole."

"MeerKAT's quality," says Rob Adam, Managing Director of SARAO, "is a testament to the dedicated effort over 15 years by hundreds of people from South African research organisations, industry, universities, and government."

The discovery of the MeerKAT bubbles relatively nearby in the centre of our home galaxy brings astronomers one step closer to understanding spectacular activities that occur in more distant cousins of the Milky Way throughout the universe.

Reference:

Inflation of 430-parsec bipolar radio bubbles in the Galactic Centre by an energetic event, by I. Heywood et al., was published in the 12 September 2019 issue of *Nature.* The article is available at https://nature.com/articles/s41586-019-1532-5

Observations of potential meteors from asteroid 101955 Bennu

Tim Cooper, Comet, Asteroid and Meteor Specialist, Shallow Sky Section

Summary

Following predictions for potential meteors from asteroid 101955 Bennu, visual observations were carried out for 13.03 hours during the period 22.78 September to 26.99 September, 2019 logging 95 meteors, of which 87 paths were plotted to determine shower association. Only five possible 'Bennu-ids' were observed, three of these during the night of 24/25 September. Several meteors appeared to emanate from a possible radiant nearby and close to the star delta Sculptoris, with five members in the 30 minutes between 25.79-25.81 September. Several Southern and Northern Taurids, and September epsilon Perseids were observed, and 71 meteors were recorded as sporadic, including meteors coincident with two possible weak centres of activity in Pisces and Cetus. Note all times in this report are in UT.

shows an additional three possible candidates on the two previous nights. All meteors were recorded as slow to medium speed.

22/23 September	19h27	mag 4	med	plot 4
24/25 September	19h44	mag 4.5	med	plot 35
24/25 September	22h26	mag 4	med	plot 51
25/26 September	18h56	mag 4.5	slow	plot 56
25/26 September	19h01	mag 4	slow	plot 58
25/26 September	19h07	mag 4	med	plot 59
25/26 September	19h09	mag 5.5	slow	plot 60
25/26 September	19h26	mag 3	med	plot 63
25/26 September	20h09	mag 3	med	plot 67
25/26 September	21h26	mag 3	med	plot 74
25/26 September	21h59	mag 2	slow	plot 80

Plots 58, 60 and 80 all had very short paths, but would fit if the possible radiant is diffuse. Plots 15, 16, 26, 27, 49 and 53 are also in reasonable alignment but were recorded as sporadic meteors (SPO) as the apparent speed was recorded as fast.

Meteors from Pisces and Cetus, RAD2 = 4, RAD3 = 4

There were no meteors plotted coincident with the FCE or UCE radiants seen in global CAMS data. There are a number of plots which are coincident with two possible centres nearby:

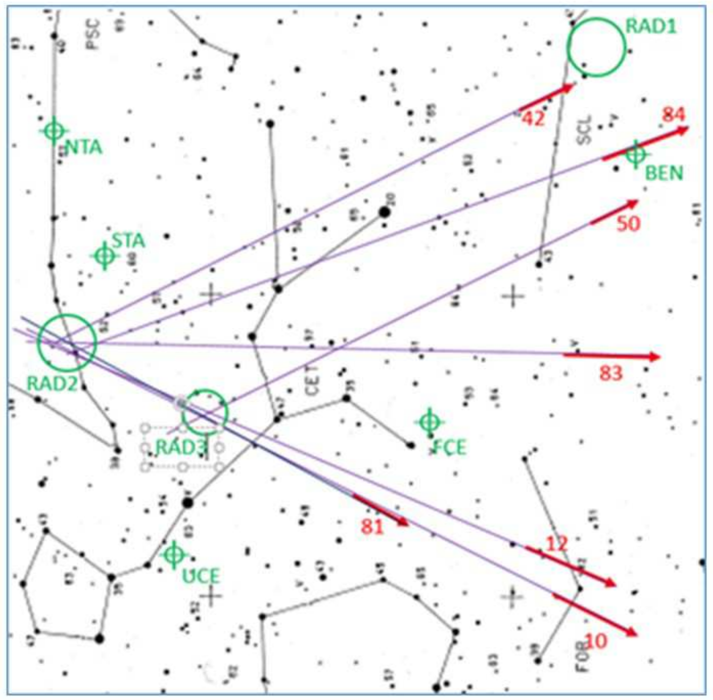

Fig 4. Portion of Gnomonic Atlas Brno map 7, showing plots of meteors coincident with RAD2 and RAD3.

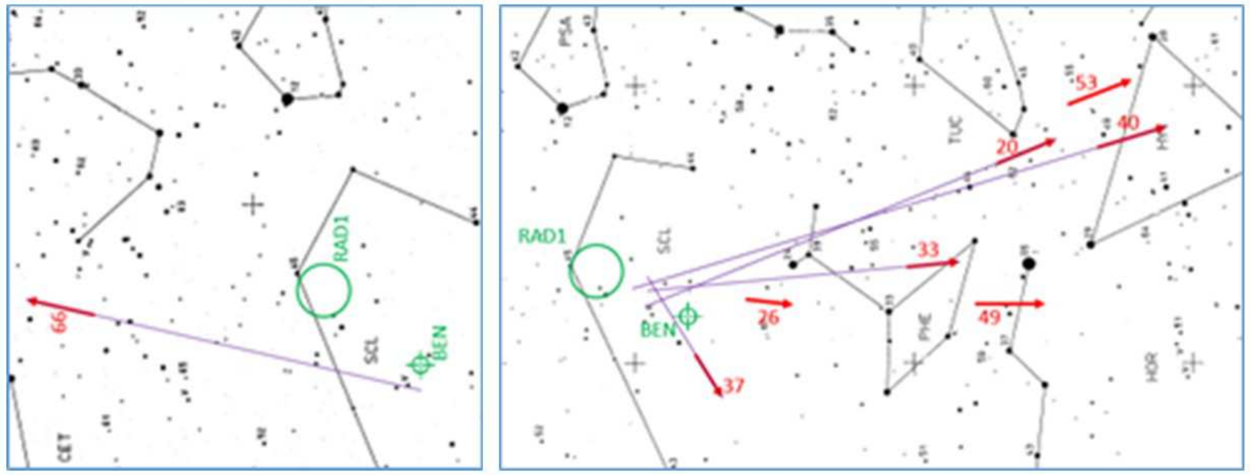

Fig 2. Portions of Gnomonic Atlas Brno maps 6 (left) and 12 (right), showing plots of meteors coincident with predicted Bennu radiant.

Plots 26, 49 and 53 also show a reasonable alignment, but were recorded as sporadic meteors (SPO) as the observed speeds were all fast, and therefore could not originate from asteroid Bennu. If the four to five candidates were Bennu-ids, then visual rates were barely perceptible during the periods of observation, perhaps exceeding the sporadic background only during the night of 24/25 September.

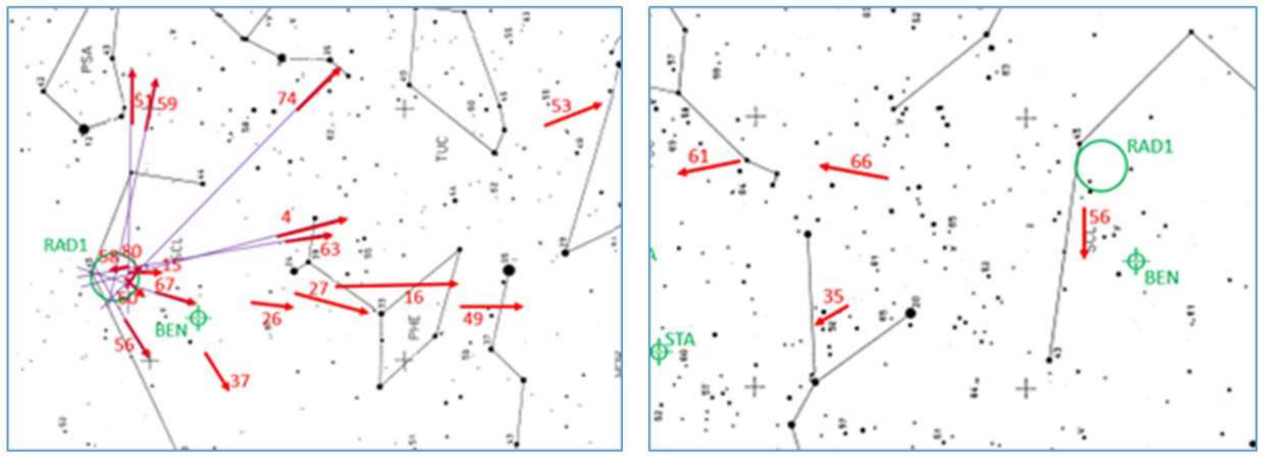

Fig 3. Portions of Gnomonic Atlas Brno maps 12 (left) and 7 (right), showing plots of meteors coincident with RAD1

Meteors from radiant RAD1 = 11

Several meteors were seen to emanate from a possible centre nearby the Bennu radiant (Figure 3), and determined to be around RA = 23h54 (358.5°), Dec –29.4°, located very close to the magnitude 4.5 star delta Sculptoris. Eight of these were observed during the night of 25/26 September, with five observed in the 30 minute interval from 18h56-19h26, shaded in grey in the list below. Inspection of the plots

Background

Asteroid 101955 Bennu (1999 RQ36) is an Apollo-type asteroid, with orbital period 1.20 years, diameter 0.492 km, rotation period 4.297 hours (Nolan et al 2013), and density 1.26 g/cm^3 (Chesley et al 2014), which implies it may be a loose collection of rubble rather than a solid body. The asteroid is the target of study by the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx), which launched on 8 September 2016, and placed in orbit around the asteroid on 31 December 2018. Part of the mission objective is the collection of materials from the surface of the asteroid in 2020 and return to Earth for analysis in 2023. Shortly after arrival at Bennu, images from OSIRIS-REx showed plumes of dust emitted from the surface on nine separate occasions, with a production rate measured on one occasion around 0.15 kg/sec (Hergenrother et al 2019). The asteroid will make a number of close approaches to Earth in the future, particularly in 2135 within 1 lunar distance, and more so between 2175 and 2196 when impacts are possible (Chesley et al 2014), including by any debris which may remain captured in orbit around Bennu. The separation between Earth and Bennu's orbit at closest approach is 0.003 AU (Ye 2019). He found that particles emitted since 1500 CE should now be starting to cross Earth's orbit, which may result in a meteor shower being visible, and with increasing probability over the next century.

Fig 1. Predicted radiant position for Bennu meteors in the constellation of Sculptor (Map adapted from Stellarium 0.13.0).

Any meteors from asteroid Bennu were expected to radiate from 00h20 (005°), –34°, in the constellation of Sculptor as shown in Figure 1. With a low geocentric velocity of

6 km/sec observed meteors would be slow moving, and were expected to be faint. Ye gave the peak time as 25.52 ± 0.25 September 2019 around the time of nodal crossing. In addition to the predicted Bennu radiant there are several other known showers active at this time of year and Table 1 lists those that were expected to be active (Lunsford 2019a), as well as two showers (FCE and UCE) detected by the global CAMS network during the days immediately prior to the author's observing period.

With this in mind the author made observations during the nights of 22/23 to 25/26 September 2019 to see if any visual meteors from Bennu could be observed, and to set a baseline for visual observations in future years.

Shower	Code	RA (°)	Dec °	Vg (speed)
Bennu	BEN*	00h20 (005)	–34	6 (very slow)
Northern Taurids	NTA	00h26 (007)	+10	28 (slow)
Southern Taurids	STA	00h46 (011)	+03	27 (slow)
September epsilon Perseids	SPE	03h34 (054)	+40	65 (fast)
Orionids	ORI	04h20 (065)	+17	67 (fast)
Nu Eridanids	NUE	05h00 (075)	+06	67 (fast)
56 Cetids	FCE	01h56 (029)	–23	45 (medium)
Upsilon Cetids	UCE	02h34 (039)	–03	61 (fast)

*Table 1. Expected shower radiants and IAU shower codes. *Note BEN is not an official shower code and is used only in this report to identify potential meteors from asteroid Bennu. Vg is the geocentric velocity of shower members in km/sec.*

Visual observations

Observations were carried out on four consecutive nights from a dark sky site from the night of 22/23 September to 25/26 September, under generally good conditions with naked eye limiting magnitude (LM) in the range 6.2-6.4. Observing periods, conditions and number of meteors observed are given in Table 2. High winds were experienced during the night of 24/25 September and up to local midnight on 25/26 September, and observations during the night of 24/25 September were terminated at 22h40 due to cloud cover for the remainder of the night. During 13.03 hours observation 95 meteors were observed of which 87 were plotted, mainly on Atlas Brno map 12, but also on maps 6 and 7 (Znojil 1988). Meteors that were observed in peripheral vision and far from the field of view (α,δ in Table 2) were not plotted since the observed path could not be defined with sufficient accuracy, and amounted to 8 meteors. Where the meteor path could be defined using more than one map I plotted the path on both maps to aid in shower assignment. Radiants identified in Table 1 were marked on the maps after all meteor paths had been plotted, following which shower associations were made, taking into account speeds of observed meteors to arrive at the number of meteors in Table 2.

Sept. 2019	Time UT	Field α,δ	T eff hours	LM	BEN	NTA	STA	RAD1	SPE	SPO	Total
22/23	1837-1937	355, -45	1.00	6.25				1		3	**4**
22/23	1958-2058	355, -45	1.00	6.35			2			4	**6**
22/23	2119-2220	355, -45	1.00	6.40		1				8	**9**
23/24	1848-1958	355, -45	1.17	6.20					1	2	**3**
23/24	2023-2123	355, -45	1.00	6.30	1					3	**4**
23/24	2131-2216	355, -45	0.75	6.25						5	**5**
23/24	2216-2249	355, -45	0.55	6.20						2	**2**
24/25	1858-2003	355, -45	1.08	6.40	2			1		4	**7**
25/25	2010-2110	355, -45	1.00	6.40	1		1			5	**7**
24/25	2137-2228	355, -45	0.85	6.40				1	1	6	**8**
24/25	2233-2240	355, -45	0.12	6.35						3	**3**
25/26	1841-1927	350, -32	0.77	6.40				5		4	**9**
25/26	1935-2039	350, -32	1.07	6.40	1	1		1		9	**12**
25/26	2103-2203	350, -32	1.00	6.40				2		6	**8**
25/26	2310-2350	350, -32	0.67	6.35		1				7	**8**
Total			**13.03**		**5**	**3**	**3**	**11**	**2**	**71**	**95**

Table 2. Periods of observation and number of observed meteors. Field α,δ is the centre of field of view in RA and Dec. both expressed in degrees. LM is the average naked eye limiting magnitude for the watch period. Number of meteors assigned to each radiant after plotting, giving consideration to the apparent speed of the meteors. Observations on 24/25 September were terminated at 22h40 UT due to cloud.

Meteors from the predicted Bennu radiant, BEN = 5

The main objective of the observing campaign was to see if there was any activity from asteroid Bennu from a radiant at about 005°, –34°. Any meteors from the asteroid were expected to be slow. Five meteors were traced to the predicted Bennu radiant, as shown in Figure 2, with four noted as slow moving, and one (plot 66) as medium speed. On that basis plot 66 may not fit the data set for this radiant, but could possibly be a fit with RAD1 described below.

23/24 September	20h42	mag 2	slow	plot 20
24/25 September	19h26	mag 5	slow	plot 33
24/25 September	19h55	mag 4.5	slow	plot 37
24/25 September	20h45	mag 2	slow	plot 40
25/26 September	19h47	mag 3	med	plot 66