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Front Cover: First MeerKAT antenna (not yet equipped with receivers)

mnassa

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Scholarships for 2014 awarded

The ASSA Scholarship has been awarded to Freya Bovim, who is in the second academic year of her studies for the B.Sc. degree at UCT.

The SAAO-ASSA Scholarships have been awarded to three students at UNISA

Verlon Etsebeth who is undertaking astronomy and mathematics modules at the second year level for the B.Sc. degree.
Dean De Villiers who is undertaking physics and mathematics modules at the first year level, and astronomy, physics and mathematics modules at the second year level for the B.Sc. degree.

Francois Botha who is taking astronomy, physics, mathematics and applied mathematics modules at the second year level for the B.Sc. degree.

(l-r) Freya Bovim, Verlon Etsebeth, Dean de Villiers, Francois Botha

Visiting the SKA Site

I.S. Glass and M.G. Soltynski

Introduction

On 17 March the MeerKAT/SKA site was opened for a tour by members of the academic community. The site has been designated a "National Key Point" and access is always likely to be restricted in the interests of avoiding Radio-Frequency Interference (RFI). The official arrangements were rather expensive but we obtained permission (along with several others, as it turned out) to travel independently to join the group in Carnarvon. The distance from Cape Town is around 600 km and it took us about 6½ hours via Clanwilliam and Calvinia to get there on Sunday 16th March, under light traffic conditions and only a few "stop-gos".

We duly met the group at the central church in Carnarvon and headed a few kilometres out of town to "Klerefontein", a farmhouse that is used as the Carnarvon office of the MeerKAT/SKA project. Here we received a safety briefing and warnings about speeding on site. We also had to turn off our cellphones. On a hill near Klerefontein is the C-BASS South telescope, not yet operational and which we did not visit. C-BASS South will eventually be used together with its twin at the Owens Valley Radio Observatory in California (C-BASS North) to map the brightness and orientation of radio waves (polarisation) of the whole radio sky at 5 GHz, corresponding to a wavelength of 6 cm. The project will greatly improve measurements of the Cosmic Microwave Background, the oldest light in the universe.

Our guide was Tony Foley from the Commissioning team and we were fortunate enough to get a lift in his official vehicle for the 80 km or so on the Carnarvon-Brandvlei dirt road to the actual site. This road is fairly boring. A 33KV special low-noise power line for the site runs along the whole way. We passed a couple of the famous “corbelled houses” that occur in this part of the Karoo, a single Kokerboom and a few springbok.

Approaching the site we could see the KAT telescope in the distance. After passing security, we went first to the farmhouse “Meysdam”, where we, or at least some of us, were issued with luminous vests and hard hats. This as a safety precaution because there are many contractors on site and a lot of civil engineering works are in progress.

Karoo Array Processor Building

Six kilometres farther on is the SKA Site Complex, situated on the south side of the Losberg koppie, which acts as a natural barrier against any radio interference this complex may generate, as the radio telescopes are located on the north side of the koppie. The central feature is the still-under-construction Karoo Array Processing Building, a large room for computers and correlators, with extensive RFI shielding. This was a hive of activity. All cables entering and leaving the building have special filters to ensure that no radiofrequency signals can escape from the building via them. Within, there is space for the MeerKAT correlators and even for the correlators and electronics of the first phase of the SKA. Of course, there is elaborate air conditioning and cooling for the racks (the outside temperature can reach the mid-forties). A long earthen hill nicknamed the “Nuweberg”been constructed from material excavated from the site of the partially underground Karoo Array Processing Building to give extra shielding in the direction of the radio telescopes.

Fig 1. *Final touches being applied to the RFI-shielded room in the Karoo Array Processor Building.*

The correlators for the KAT telescope are currently in two special containers nearby.

Close by is a large power generation installation to ensure a continuous supply should the Eskom supply be interrupted. Three massive flywheels store sufficient energy for a few seconds of operation and can start the 4.8MW of diesel generators very rapidly by engaging a clutch. The diesel engines are kept warm at all times to ensure a quick start.

What is a Correlator?

A radio telescope array is a way to simulate a giant telescope that is the equivalent in size of the area on the ground occupied by the individual antennas. A single large dish is not usually a practical proposition from a construction and cost point of view. However, combining the signals from each antenna of an array to form an image brings its own complications. The signals from each antenna are first digitized at a very high sampling rate. Then they must all be correlated with each other and the results of the correlations must be Fourier transformed to generate the image. The larger the scale of the telescope the more detail is revealed but shorter baselines are also needed to fill in the coarser details. The array must also be two-dimensional if a two-dimensional image is to be produced (unless there is time to wait for the earth to rotate sufficiently to change the antenna orientation with respect to space). Hence the need for large numbers of antennas in a spiral or other two-dimensional pattern. The size of the individual dishes and the number of them determines the sensitivity of the overall telescope, assuming that the receivers are the best available for the wavelength (for a further but more technical explanation see https://astronomy.swin.edu.au/cosmos/C/Correlator).

The area of sky observed by a simple dipole array is largely a matter of the software employed in the correlator and the computer power available. However, an array of parabolic antennas is also limited by the field observable by the individual telescopes.

Assembly Buildings

Also close by are two Assembly Buildings, in one of which the dish of the first MeerKAT antenna of 13.5m x 15m was being completed. When we saw it, the support frame was complete and the first of the surface panels had been installed.

Fig 2. *The first MeerKAT dish being assembled.*

KAT Telescope

We then went to the KAT telescope comprising seven prime-focus antennas of 12m diameter (see Wikipedia KAT-7 article for the technical specifications). Suffice to say that it operates at 1.2 to 1.95GHz (25 to 15cm wavelength. The dish construction is of fibreglass. The KAT-7 is a working instrument, although it was originally intended only as an engineering and science prototype for the MeerKAT, and it has already been used for several scientific observations. KAT-7 was not in operation when we were there but one of the antennas was set in motion so that we could see how it pointed and tracked. The receiver system of each dish is cryogenically cooled to about 70K (-203°C) in order to increase the system's sensitivity by reducing the noise level. Close by is a rig where one of the MeerKAT receivers is being tested and also the place where the first MeerKAT antenna is about to be erected.

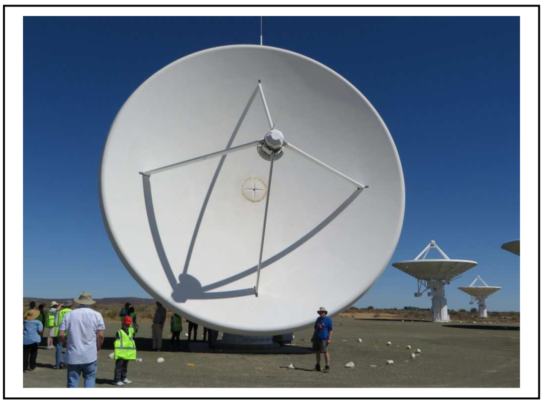

Fig 3. *One of the antennas of the KAT-7 array.*

Fig 4. *The receiver at the focus of a KAT antenna.*

PAPER Experiment

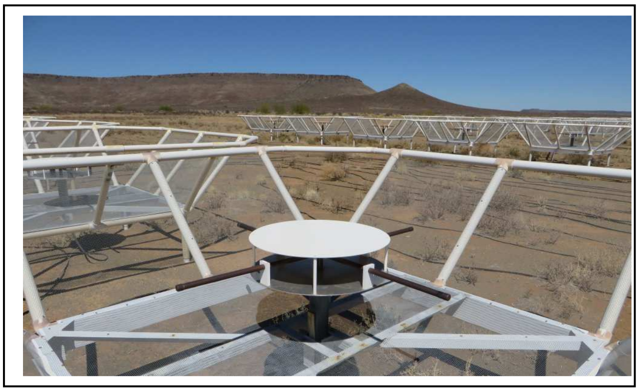

Fig 5. *One of the 128 antennas of the PAPER array. The dipoles are about 1m long, to be tuned to a wavelength of about 2m. The use of two dipoles means that both polarisations can be observed.*

Also on the site is the PAPER (Precision Array for Probing the Epoch of Reionization) array of 128 small antennas operating over a band of frequencies centred around 150MHz (2m wavelength). It uses intensity mapping of redshifted (z=7-12) 21cm emission of neutral hydrogen to try to measure the power spectrum of fluctuations in the intergalactic medium introduced by the first luminous sources in the universe (see http://eor.berkeley.edu/ for details and further references). This is a precursor for a future larger and more sensitive programme called HERA (see http://reionization.org/) and is a collaboration of various US institutions with the NRF in South Africa. Particularly interesting is the simple way in which the small antennas are constructed, with a lot of use made of standard PVC pipes and fittings in the support structure.

Fig 5. *Part of the PAPER array showing where the cables from the 128 telescopes come together.*

MeerKAT site

Finally we were taken to see some of the 64 concrete and steel foundations for the MeerKAT antennas. They will be used at first in the "L-Band" which is a frequency range in the electromagnetic spectrum that contains the hyperfine transition of neutral atomic hydrogen at 1420 MHz. Parts of the L-band are protected radio astronomy allocations worldwide, and the frequency range that will become operational in the first phase of MeerKAT will cover 1.00 to 1.75 GHz (30cm to 17cm wavelength). These antennas are of an offset Gregorian design to reduce the unwanted polarisation effects caused by a central obstruction. The elliptical outline of a dish makes it appear circular from the point of view of the offset focus. The first completed antenna was due to be inaugurated by President Zuma on 27 March 2014 [In fact, The Minister of Science and Technology appeared in his stead].

By the end of 2015 an array of 16 MeerKAT antennas will be commissioned and ready to do science. A year later all 64 antenna positioners will be in place, and in mid 2017 the full MeerKAT array will be in action. Nearby, construction of Phase 1 of the SKA will take place from 2018 to 2020, providing an operational array capable of carrying out the first science. Phase 2 will then follow for completion in 2025.

[Photo credits: authors]

AMATEUR OPTICAL TRACKING IN SOUTH AFRICA DURING 1957-2014

Greg Roberts

Abstract*: This is the second article of what is planned to be several covering the history of amateur satellite tracking in South Africa during the period 1957 to the present. It will concentrate almost exclusively on optical tracking rather than being a complete record of optical and radio tracking and will only handle observers who reported scientific data to the various tracking networks. Besides Moonwatch several other organisations were interested in amateur optical observations. Only those involving South Africa will be briefly described.*

Catering For the "Lone-Wolf" observer

As mentioned in the first article the MOONWATCH program, for logistical and other reasons, did not in its early years encourage or cater for "lone-wolf" observers, so several other organizations sprang into existence to make use of this untapped potential. Despite several intensive searches, especially on the internet, the author has been unable to locate any history or major documentation on these organisations so has had to rely mainly on his personal experiences and recollections so this is an incomplete record.

If anyone has any additional information on these groups it would be much appreciated.

Western Satellite Research Network

Early in the MOONWATCH program several of the more experienced MOONWATCH teams felt that routine visual observations were of comparatively little value for "well-behaved" satellites and that there was also a need to cater for those excluded from **Moonwatch** because of SAO's "lone-wolf" discrimination. With financial support from North American Aviations Space and Information Systems Division and the United States Air Defence Command (ADC) the Western Satellite Research Network (WSRN) was formed in July 1959 by two engineers at North American Aviation, namely Gary A. McCue and Richard Angel. They believed that experienced visual observers could make significant contributions to some of the more specialized problems of satellite tracking and history has proved this correct.

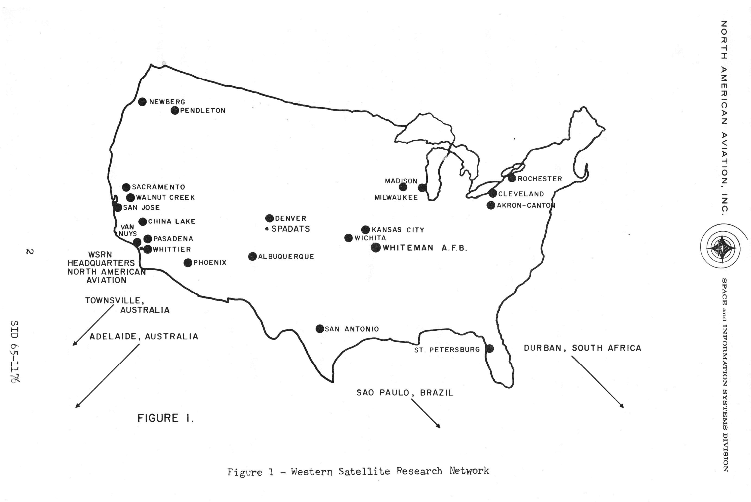

Fig 1. *The WSRN network.*

By observing the magnitude and other characteristics such as tumble rate or variability in brightness it is possible to identify the nature and condition of satellites, for example observations of spin rate increase could indicate leaks or ruptures in the satellite’s pressurized systems. The flash pattern and magnitude variation enable one to determine the general nature of a satellites surfaces and its orientation - i.e. whether spinning, stabilized or regular or irregular tumbling.

Today this is recognized as the first stage in the evolution of Space Situational Awareness (SSA) which is invaluable for scientific or military use and which lasted from 1957 to 1964 and focussed on the fundamental requirements for detection, tracking and identification of a small but rapidly growing number of artificial earth satellites and associated pieces of space debris.

In 1959 eight WSRN teams contributed more than half of all American visual satellite observations and by mid-1964 the organization had grown to 25 teams with 82 observing sites in North America, Australia, South America, and South Africa (Durban), and later (1966) South Africa (Cape Town).

The observations made were of value primarily when photographic or electronic methods were inadequate, i.e. the satellite was too small, too distant or had poorly determined orbital elements, so consequently WSRN concentrated on recovering lost satellites, tracking faint problem objects, observing unusual launches and satellite decays in the atmosphere, and recording the distinctive optical characteristics of individual objects thus making WSRN an integral part of the US national space surveillance system.

The program was co-ordinated by North American Aviation's SPACE Sciences Laboratory in Downey, California using an IBM 7094 computer which could produce 2000 "look-angle" predictions per minute. Approximately 50000 predictions were distributed each month, either telephoned, telegraphed or air mailed depending on the urgency of the situation.

Observations made were reported to WSRN Headquarters in Downey and telegraphed promptly to the Spacetrack centre in Colorado Springs, Colorado.

STATION NAME	MJD	Y M D	H M	MAX	MIN	AMAX	AMIN	PERIOD	FLASH	ALT	AZ	RANGE	COMMENTS	--OBS	PHASE
OCEANPORT	39551	67/ 3/ 2	0 36	13.0		6.6				56.3	356.1	19000.	+11 FLARE	--GFG	78.8
OCEANPORT	39552	67/ 3/ 3	0 35	13.5		7.1				56.3	355.5	19000.	+11.5 FLARE	--GFG	79.6
OCEANPORT	39552	67/ 3/ 3	1 36	13.5		6.8				59.5	4.0	22200.	+13.5 TO INV.	--GFG	70.0
OCEANPORT	39552	67/ 3/ 3	23 49	13.0		7.0				54.7	342.5	15600.	+13 TO INV.	--GFG	90.6
OCEANPORT	39553	67/ 3/ 4	0 35	13.0		6.6				56.2	355.0	19000.	+11.5 FLARE	--GFG	80.2
OCEANPORT	39557	67/ 3/ 8	0 30	12.5		6.1				56.1	353.2	19100.		--GFG	82.9
OCEANPORT	39559	67/ 3/10	1 29	13.0		6.3				60.0	359.4	22200.	+13 FLARE	--GFG	74.7
OCEANPORT	39560	67/ 3/11	1 27	13.0		6.3				59.9	358.6	22300.		--GFG	75.6
VAN NUYS-F	39910	68/ 2/24	7 17	10.8	11.5	5.9	6.6			64.0	214.0	9440.	TP ABOUT 2 MINUTES, FLICKER	--JGW	26.5
VAN NUYS-F	39911	68/ 2/25	7 10	10.5	11.5	5.6	6.6	94.00		65.0	213.0	9420.		--JGW	27.4
VAN NUYS-F	39933	68/ 3/18	4 40	10.7	11.5	5.9	6.7			67.0	167.0	9160.		--JGW	46.1
VAN NUYS-F	39934	68/ 3/19	4 33	10.3	11.3	5.5	6.5	92.00		67.0	164.0	9160.	FLICKER TOO.	--JGW	46.7
VAN NUYS-F	39935	68/ 3/20	4 26	10.2	11.2	5.4	6.4	93.00		67.0	162.0	9150.	SOME MAX AT HALF PERIOD	--JGW	47.7

- 142 -

SDC NO. 899 64-64A EXPLORER 22 USA LAUNCHED 64/10/10 IN ORBIT
PERIOD = 104.8 PERIGEE = 550.5 APOGEE = 672.3 INCL = 79.7

SD68-629

STATION NAME	MJD	Y M D	H M	MAX	MIN	AMAX	AMIN	PERIOD	FLASH	ALT	AZ	RANGE	COMMENTS	--OBS	PHASE
DURBAN B	38937	65/ 6/26	17 20	6.5	6.5	7.4	7.4			89.0	209.0	660.	STEADY	--AA	62.0
DURBAN B	38938	65/ 6/27	17 47	6.5	6.5	6.7	6.7			47.0	266.0	900.	STEADY	--AA	98.1
DURBAN B	38939	65/ 6/28	16 30	6.5		7.0				47.0	94.0	800.	SCINTILLATING	--AA	31.3
DURBAN B	38940	65/ 6/29	16 57	6.5	6.5	7.4	7.4			87.0	253.0	660.	STEADY	--GR	69.3
DURBAN B	38941	65/ 6/30	17 25	7.5	7.5	7.9	7.9			45.0	266.0	850.	STEADY	--AA	104.6
DURBAN B	38942	65/ 7/ 1	16 7	8.0	8.0	8.4	8.4			49.0	93.0	840.	SCINTILLATING	--GR	38.7
DURBAN B	38943	65/ 7/ 2	16 25	7.0	7.0	7.9	7.9			83.5	260.0	660.	STEADY	--GR	79.4
DURBAN B	38944	65/ 7/ 3	17 3	3.0	7.5	3.2	7.7			41.0	266.0	920.	REACHED +3 ONCE IN A FLASH	--GR	112.8
DURBAN B	38950	65/ 7/ 9	16 17	7.0	7.0	7.2	7.2			38.0	266.0	920.	STEADY	--AA	123.9
STADE/ELBE	38973	65/ 8/ 1	1 20	7.0	7.5	8.2	8.7			87.0	100.0	570.	STEADY AND FAINT VARYING	-- HK	76.5
STADE/ELBE	38999	65/ 8/27	21 54	7.5	7.5	8.6	8.6			75.0	260.0	603.	STEADY	-- HK	70.7
STADE/ELBE	39057	65/10/24	4 20	8.0	8.0	8.4	8.4			50.0	260.0	830.	STEADY	-- HK	34.3
STPETERSBURG	39814	67/11/20	0 38	9.0		0.0		1.50		26.1	161.9			-- FK	71.2
STPETERSBURG	39817	67/11/23	0 18	7.0	7.0	0.0	0.0			56.0	80.7			-- FK	33.8
GRANBY	39819	67/11/25	23 59	8.0	8.2	9.0	9.2			78.0	256.0	640.	IRREG. VARYING	--MPC	73.1
STPETERSBURG	39821	67/11/27	0 22	7.0	7.0	0.0	0.0			66.9	297.2			-- FK	85.1

Fig 2. *A sample WSRN report.*

Several reports on such optical characteristics were issued as follows (and may be found on the Internet).

Satellite Optical Characteristics Study SID 65-1176, 1 August 1965, North American Aviation, Inc, Space and Information Systems Division. Contains 11 000 observations of 365 satellites made by 26 teams of the WSRN. 175 pages.

Optical Observations Of Faint Satellites (Final Report), Technical Document Report No ESD-TDR-65-155 July 1964

Satellite Optical Characteristics Catalogue SID68-629. 20 July 1968, North American Rockwell Corporation, Space Division. Contains 7900 observations of optical characteristics of 574 satellites, 356 pages

Optical Characteristics of Artificial Satellites SID 70-55 1 July 1970

The following credits appear in these reports:

Particular thanks must be given to the members of the WSRN teams who have donated a considerable amount of time to this project. Without their unselfish efforts preparation of this report would not have been possible. The contributions of the following individuals are particularly noteworthy (given in order listed):

M. McCants, Austin, Texas; G. Roberts, Durban, South Africa; P. Maley, Edinburgh and San Antonia, Texas; D. Brierley, Poynton, England; A. Beresford, Adelaide, Australia; (after the initial three listed only those still tracking in 2013 are given)

Observations of all the Apollo Spacecraft were made during translunar coast. Six WSRN teams reported observations of Apollo 12 including several sightings at ranges in excess of 280 000 km with magnitudes between +12 and +13. Depending upon the difficulty of the object, the instruments used by WSRN observers ranged in size from the naked eye to the 18-inch refractor at Granby, Massachusetts, or the 20-inch reflector and 26.5-inch Innes refractors at the Republic Observatory, Johannesburg.

In addition a regular newsletter was issued giving current priorities and recent achievements as well as papers of interest to observers. Meetings were held for geographically suited members.

It was primarily as a result of a paper entitled **Space Surveillance Technical Memorandum** No 68-4, issued by the 1st Aerospace Control Squadron, ENT Air Force Base, Colorado on "A Preliminary Analysis of Molniya orbits" and specifically sent to the author with the comment "I'm sure you will find it very informative" that the author acquired his interest in tracking high altitude faint satellites which has lasted to the present day.

Over the approximately ten years that WSRN operated it acquired a total of over 22 000 optical observations and provided a comprehensive summary of optical appearance data that would serve in future years as a valuable aid for the identification of the nature or condition of a satellite.

A write-up about WSRN appeared in ***Sky and Telescope*** Vol XXX No 2, August 1965 **Western Satellite Research Network** , Pages 88-90.

Phototrack

The **Phototrack** program was set up to provide valuable support to the operation of the twelve Baker-Nunn cameras that formed the prime optical tracking network since even if the Baker Nunn cameras operated at maximum efficiency they were restricted by weather and other problems.

It was set up by the Society of Photographic Scientists and Engineers in the United States and encouraged volunteers to obtain photographic records of satellite tracks against a background of stars. Negatives had to be ideally at least 4 in. by 5 in. and taken with a lens of at least 5-in. focal length and show the track of the satellite orbit against a fixed starfield background with the trace containing two gaps, or displacements, timed to an accuracy of 0.1 sec using time signals broadcast by station WWV on 5,10,15,20,25 or 30 Mhz.

The programme was directed by Norton Goodwin., by profession a tax lawyer and a keen amateur photographer. Norton appears to have been a man of many talents and the writer did not know where he found the time to practice as a lawyer but it is believed he was financially quite well off (and single!) so could indulge in other activities. It appears to have been a limited staff project and operated with a grant from the Office Of Research Grants, NASA.

All negatives were to be accompanied by a form listing all the required technical information and forwarded to the Secretary-Treasurer of the Society of Photographic Scientists and Engineers at 826 Connecticut Avenue, Washington 6, D.C. USA which was the address of Norton's legal practice.

Project Moonbeam

In addition Norton Goodwin established **Project Moonbeam** in conjunction with the American Amateur Relay League (ARRL) for the radio tracking of satellites by radio amateurs and other electronic enthusiasts. These amateur stations provided tracking data that could be used for inquisitional purposes, the resolution of small perturbations in the orbit due to localized gravitational anomalies , the influence of the ionosphere upon radio signals and supplementary data in case of premature failure of the satellite transmitter or short life of the satellite. The program was similar to **Moonwatch** with general headquarters at the United States Naval Research Laboratory with the Jet Propulsion Laboratory of the California Institute of Technology assisting and providing a **Moonbeam** information office. The ARRL assisted by publishing design information and other related information in its monthly publication "QST". Although this series of articles will concentrate on optical tracking some brief mention will be made in future articles where South Africa was involved in **Moonbeam**.

Volunteer Satellite Tracking Program - later renamed the Independent Tracking Coordination Program (ITCP)

Norton Goodwin also established the Volunteer Satellite Tracking Program (VSTP) at about the same time as the Phototrack and Moonbeam programs. It is not known how large an organisation VSTP was but many of the members were well known names in the satellite "profession" so it did enjoy considerable support and played a major role in several organizations.

This organisation had a major influence on the author when he was contacted by one of the leading observers - Wilcox Overbeck - and asked if he was interested in providing optical observations from the southern hemisphere and as a result a close friendship and collaboration developed, ably assisted by Norton Goodwin, which lasted for several years until contact was lost.

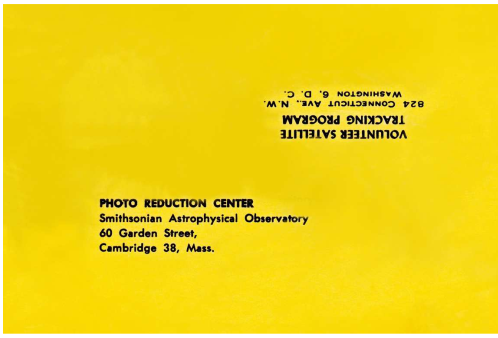

Fig 3. *Photo reduction address.*

Wilcox P.Overbeck, known as "Bill", was a man of considerable talents. He attended the University of Chicago and worked with Enrico Fermi as part of the Manhattan Project and was one of the 49 scientists that made history on 2 Dec 1942 when Chicago Ile 1 (CP-1) went critical and produced the world’s first self-sustaining controlled nuclear chain reaction. He also held 14 patents related to atomic energy and at the time of his involvement with VSTP and ITCP produced numerous scientific papers related to satellite tracking. In his professional capacity he was director of the Savannah River Laboratories of the U.S. Atomic Energy Commission until a brain tumour apparently terminated his career and interest in satellites. He battled cancer for 10 years before dying from arteriosclerosis in 1981.

To assist the writer Bill wrote two publications that for a period served as the "amateur satellite trackers bible" as it described the techniques used by Bill to predict and analyse his observation and was distributed free to all members of the VSTP. This publication was called "A Letter to Gregory Roberts" and described Bill's method of predicting positions of artificial satellites at the point of local culmination. Bill proved that it was possible for an individual to maintain accurate orbital data on a large number of satellites using modest equipment and his own observations - recall that in those days micro-computers did not exist so one had to use mechanical hand calculators, logarithm tables and other computing aids! This "Letter" subsequently resulted in **Moonwatch** approaching the writer to set up a **Moonwatch** station, but more of this later.

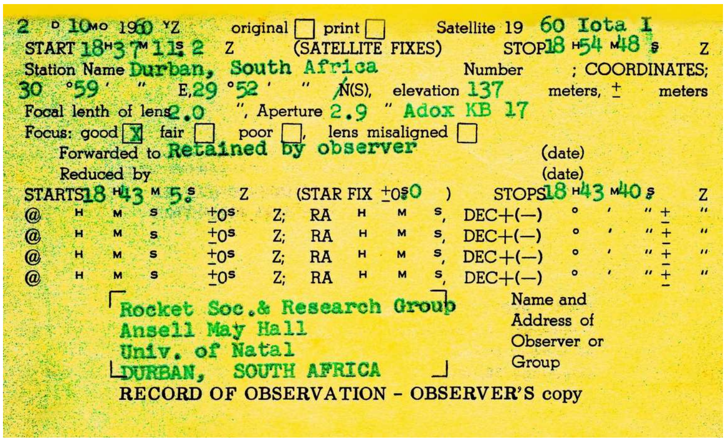
2 D 10 MO 1960 YZ original print Satellite 19 60 Iota I
START 18 H 37 M 11.2 S Z (SATELLITE FIXES) STOP 18 H 54 M 48 S Z
Station Name Durban, South Africa Number ; COORDINATES;
30 °59 ' " E, 29 °52 ' " N(S), elevation 137 meters, ± meters
Focal lenth of lens 2.0 ", Aperture 2.9 " Adox KB 17
Focus: good [X] fair [ ] poor [ ], lens misaligned [ ]
Forwarded to Retained by observer (date)
Reduced by (date)
STARTS 18 H 43 M 5. S Z (STAR FIX ±0.0 S) STOPS 18 H 43 M 40 S Z
@ H M S ±0 S Z; RA H M S, DEC+(−) ° ' " ± "
@ H M S ±0 S Z; RA H M S, DEC+(−) ° ' " ± "
@ H M S ±0 S Z; RA H M S, DEC+(−) ° ' " ± "
@ H M S ±0 S Z; RA H M S, DEC+(−) ° ' " ± "
Rocket Soc.& Research Group
Ansell May Hall
Univ. of Natal
DURBAN, SOUTH AFRICA
Name and Address of Observer or Group
RECORD OF OBSERVATION - OBSERVER'S copy

Fig 4. *Photo reduction data*

In the 20 July Report to the Office of Research Grants and Contract, NASA Norton Goodwin for the period 1 April - 30 June 1964 had this to say :

"It will be noted that the mean orbital elements supplied by Gregory Roberts and Arthur Arnold were based solely on observations made at Durban, South Africa. The data obtained by Roberts and Arnold are of use to anyone in the world having an interest in acquiring 1963-14A or 1962 Kappa 1 during a period from 30 to 60 days after issue. The analytical procedure was carried out with the aid of a desk calculator, following methods suggested by W. P. Overbeck's "A Letter to Gregory Roberts", which has been published as part of the ITCP Program. This is the first known instance of amateurs producing satellite orbital data for use by others.

MODIFIED ORBIT ELEMENTS 18 Jun

BRIGHT	-28.8	-26,-30	-4	+3	-8,-20	-16,-28
OBJECT	63 014A	62 010A	60 009A	64 004A	64 005A	63 053A
NAME	Atl.Agena	Midas 5	Echo 1	Echo 2	Saturn 5	Expl 19
SOURCE	Durban*	Durban*	Norad	SAO	SAO	SAO
EPOCH of	19 Jun	19 Jun	13 Jun	20 Jun	20 Jun	20 Jun
perigee	00H	10H	09H	01H	02H	01H
(UT)	17M346	45M045	38M15	45M66	05M79	10M28
INCLIN.	87A310	86A705	47A30	81A47	31A45	78A62
NODE W.	080A316	060A070	009A93	014A22	338A94	024A61
MPD - 1D	-04M3164	-04M5056	-17M15	-07M18	-29M78	-07M78
PERIGEE	292A181	116A440	061A89	135A79	135A65	161A05
change/P	-A11702	-A13042	+A255	-A13272	+A66797	-A15244
A. PERIOD	166M4257	152M9816	114M328	108M714	94M237	115M594
change/P	-M00000	-M00000	-M00030	-M00010	-M00033	-M00019
ECCEN.	U00660	U02906	U05459	U02347	U03343	U11288
P. RADIUS	6180#87	5716#51	4584#2	4579#3	4118#8	4333#6
freq. X6/S	Tumbling	Tumbling		136T020		
REMARKS	very slow	per.13 sec.		136T170		
R. A. NODE	191A1843	008A9299	036A34	280A32	320A64	261A06

*Elements supplied by Gregory Roberts and Arthur Arnold, 62 Dragonwyck, 7 St. Georges Street, Durban, South Africa.

Fig 5. *Roberts-Arnold elements.*

In addition Bill had access to a computer at his place of work and wrote several FORTRAN programs related to satellite tracking and was the prime motivation for the author to learn how to program a computer when the South African Astronomical Observatory, where the author was employed, acquired its first NOVA mini-computer.

The collaboration with Bill and Norton lasted into the mid 70s and faded out - probably as a result of Bill's failing health which the writer only found out about several decades later from his son. Bill and Norton were the writers mentors and he owes them a deep debt of gratitude for teaching and encouraging an interest in the optical and radio tracking of satellites. Despite an intensive search on the Internet it has not been possible to establish what eventually happened to ITCP and Norton - probably Bill's illness contributed to its eventual closedown as he was the leading "light" of the observers.

British Satellite Tracking

In compiling the short history of the British satellite tracking activities the writer has extracted material from an article written by Desmond King-Hele in September 1987 shortly before he retired from the Royal Aircraft Establishment (RAE). Some information was also obtained from a nearly 11-hour tape recorded interview of King-Hele by the British Library Board in 2010 as part of the series of National Life Stories - An Oral History Of British Science. This is a fascinating transcript as it gives insight into why Britain decided not to develop its own rocket - Blue Streak and Black Night, for example, and decided to go instead for manned V-bomber aircraft, and why Britain never really got into space research or had its own space program, primarily as a result of the opposition of the Astronomer Royal Sir Richard Woolley, who thought space research a waste of money that could be better spent on astronomy. King-Hele also refers to Prime Minister Margaret Thatcher's *disastrous dastardly destructiveness* (his words!) in closing down the RAE and the Royal Greenwich Observatory. Information was also extracted from several of King-Heles books, principally a "Tapestry of Orbits". As Chairman of the British National Committee for the History of Science, Medicine and Technology and Deputy Chairman of the British National Committee on Space Research he is more than qualified to overview the situation.

King-Hele joined the RAE in 1948 where he remained for 40 years and initially worked in the Guided Weapons Department on scram-jets. In the mid 1950's he wrote several papers on artificial satellites so that when Sputnik 1 was launched in October 1957 he was already considered a world authority and was nominally in charge of the RAE prediction Service. In the years that followed he and co-worker Doreen Walker published numerous papers and books dealing with the behaviour of satellite orbits in an atmosphere, which are still regarded today as *the* textbooks on the subject. One of his books - **Observing Earth Satellites**, which ran to two editions, is one of the very few good books that deals with this subject and is highly recommended.

The National Prediction service, as it was known, began life at the Royal Greenwich Observatory (RGO) and was set up to basically provide satellite predictions for British observers - professional and amateur, but it only lasted at RGO for three hectic months, which set the pattern for the future. To quote King-Hele "*The prediction service at the Royal Greenwich observatory, Herstmonceux, soon ran into a serious obstacle in the form of Dr. Richard Woolley, the Astronomer Royal, who controlled the RGO, and was not at all keen on space. Consequently the service was transferred to the RAE at the beginning of 1958. Woolley's hostility to space was another* *stroke of luck because it meant the RAE received all the UK Visual and radar observations*"

Whilst at RGO, under the Nautical Almanac Office, (Oct 1957 to Jan 1958) the chief predictor was Gordon Taylor who was also a very accurate satellite visual observer. But again it was not thought suitable for RAE and was transferred to the Radio and Space Research Station (RSRS), at Ditton Park, Slough where it remained for 22 years, by which time the RSRS had changed its name to Appleton Laboratory and had then been bodily removed to Chilton.

In 1975 **Moonwatch** closed down and most of the productive observers were added to the Appleton mailing list so this did not materially affect the flow of optical observations. However the psychological damage is what mattered. To quote King-Hele "*Visual observing is an exacting and financially unrewarding activity task: observers need to feel they are wanted if they are to give of their time and to brave the winter weather. The brutal message from the USA was that they were no longer wanted*".

Some memorable names from the Appleton Laboratory period are Doreen Walker who was chief predictor (Jan 1958 to Dec 1958), Russell Eberst (1958-1962), Alan Pilkinton (1962-1964) and Pierre Neirinck (1966-1981). Pierre deserves special mention and towards the end at Appleton the staff consisted essentially of two people - Pierre in the day and Pierre at night! (he was always available at any time!)

The Hewitt camera played a major role. This was designed by Joseph Hewitt (1912-1975) of the Royal Radar Establishment, Malvern as it was then called. The purpose of the cameras was to record the re-entry of the British Blue Streak missile and two cameras had already been manufactured by Grubb Parsons when Blue Streak was cancelled. The cameras were considered to be useful for satellite observation and one camera was set up at Sheriffs Lench and was known as the **Malvern Hewitt**, with the other at Lye Vallets, which was subsequently moved in

1964 to the Royal Observatory Edinburg (ROE) and was known as the **Earlyburn Hewittt.** It remained in operation till 1975 after which it was placed in storage. The Malvern camera moved to RGO at Herstmonceux around 1982 with the closure of Sheriffs Lench, while the second camera was moved to Siding Spring in Australia. Both cameras were in operation from 1982 to 1990, ending with the closure of the RGO at Herstmonceux. The RGO camera is now in storage whilst the Australian one has been dismantled and the 34-inch diameter primary mirror is now in the possession of an Australian amateur astronomer.

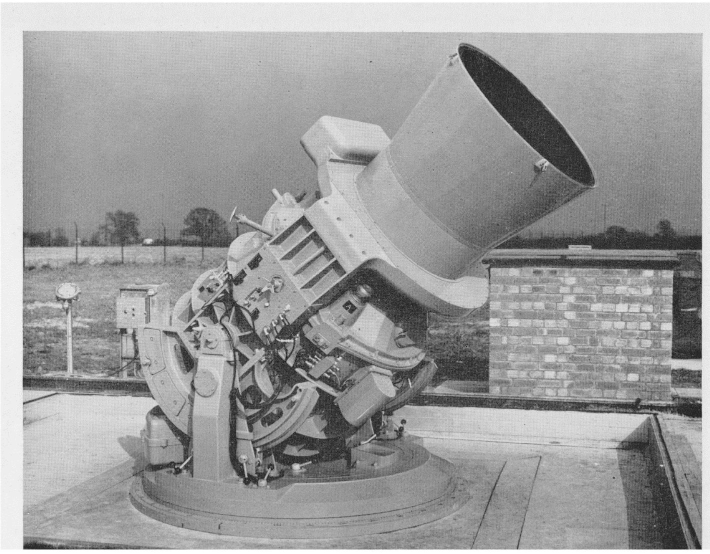

Fig 6*. The Hewitt camera developed at the Royal Radar Establishment, Malvern. The camera has an aperture of 14 inches (61 cm) and can photograph satellites with a directional accuracy of 1 second of arc*.

In 1974 the Earth Satellite Research Unit (ESRU) was set up at the University of Aston and in July 1980 the prediction service was transferred from Appleton to ESRU where it ran until March 1988 when RGO agreed to take over the two Hewitt cameras and the prediction service. The chief predictors at the Earth Satellite Unit were Fiona Lawler, Chris Cooke, Vanda Bennett and Carol Durows.

Kinethodolites also played a major role. Originally used during World War II by the Germans at the Peenmunde test site where the V1 and V2 rockets were developed, they were used after the war for tracking missiles on the test ranges of the RAE and five were converted for satellite tracking in 1957. Russell Eberst worked on one of the camera's when it was at the Royal Observatory, Edinburgh

The RGO Kinetheodolite was moved to the South African Astronomical Observatory, where it was operated most successfully for 12 years, thanks largely to the efforts of Walter Grimwood who accompanied the Kine when it was moved to South Africa after having operated it at RGO, and it provided a wealth of observations on over 40 000 transits and contributed vitally to the accuracy and immeasurability to the reliability of orbit determination.

Since the Kine was more than 25 years old and was wearing out it finally closed down in 1981 and returned to the UK where it apparently became a museum piece. Wally Grimwood retired and he died in April 1982.

(There is some uncertainty as to when the Kine was actually moved to the Cape as King-Hele states 1969 but this is incorrect as the author observed with it numerous times in 1968 as a part-time Kine satellite tracker).

The Kine at the SAAO will be discussed in greater detail in a future article.

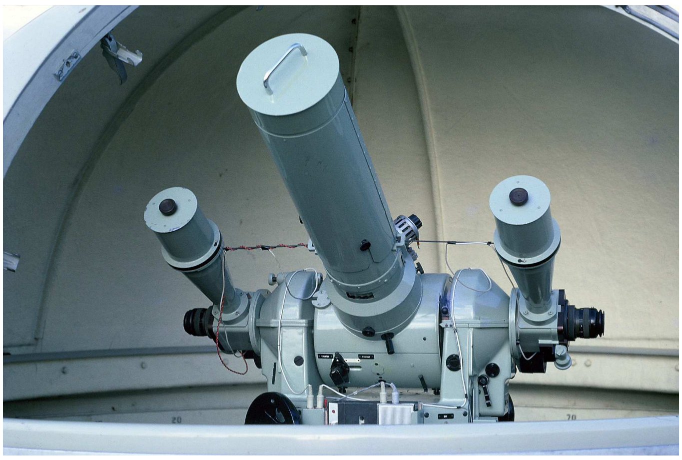

Fig 7. *The Kinetheodolite in 1968 (Greg Roberts).*

To quote King-Hele - "*Throughout the 1980's there was no flagging in enthusiasm, productivity or accuracy among the visual observers who received predictions from, and sent observations, to ESRU. Each year the observers made about 20 000 observations. Russell Eberst had made 100 000 observations by 1980 and David Hopkins reached this target in 1986. Other skilled and prolific British observers in the 1970's and 1980's were David Brierley, Peter Wakelin and Mike Waterman. All these observers, and others, achieved a very high standard of excellence - a higher standard than in most professions*."

Special mention has to be made of Bill Hirst, who after retiring as **Moonwatch** chief in the USA returned to Bergvliet (near Cape Town), South Africa were he became the most prolific observer from the southern hemisphere until **Moonwatch** closed down in 1975.

King-Hele retired in May 1988 but by then the writing was on the wall. In May 1990 the two Hewitt cameras were shut down. The prediction service for visual observers continued from RGO but most observers had withdrawn, finding their morale undermined by the apparent lack of appreciation for their work. As King-Hele put it so well "*If the Hewitt cameras are unwanted, visual observations must be supremely useless*".

So ended the era of amateur visual observers reporting scientifically useful data for use by professional space scientists, but was this the end of amateur satellite tracking?

A new direction

Many of the more dedicated observers, after having dedicated several decades of their life, felt the need to do *something* useful, even if purely for the satisfaction of doing something mentally stimulating, so there was now a new direction - the searching, location and derivation of orbital data for satellites not available in the public domain because the data was *classified* for one or other reason.

David Hopkins was probably the originator of this mode and by the mid 1980's was already maintaining his own data on about fifty satellites. Several other observers forwarded their observations to him. In Canada Ted Molczan often published these elements on the bulletin board of the Canadian Space Society and in the late 80's the author again became interested in optically tracking satellites but now interested in classified satellites.

In December 1994 the newsgroup called *SeeSAT* was created on the Internet by Walter Nissen and Bart De Pontieu with the intention of catering for all aspects of visual observing. Initially there was some opposition from some participants on the posting of data on classified satellites, and after the Twin Towers 9/11 event such data ceased to be posted, although a more private newsgroup was created by the main classified satellite trackers. After a short period, posting resumed to SeeSat and in July 2002 Ted Molczan took over the SeeSat newsgroup and its remains active to this day with approximately 1 000 subscribers - most of whom are so-called ***lurkers***.

Today optical observing of classified satellites is the main activity with approximately two dozen active observers at most. Numerous observations are also reported on the optical characteristics of all satellites seen and a large database is maintained, so satellite tracking is alive and well today.

Many of the observers from the **Moonwatch** and subsequent era, and mentioned by name in this article are still active - mostly from the former WSRN, ITCP and British observers with the fortunate addition of new and younger observers. Technology has changed the way things are done and observations are of professional capability and often surpassing the accuracy that was obtained with some of the prime instruments of the 1960-1990 era.

Russell Eberst continues to observe and remains the world’s most prolific observer and expects to reach 250 000 observations in 2015. David Hopkins has retired from satellite tracking, and the oldest tracker is Pierre Neirinck. Several trackers have since passes on - Bill Hirst is one such person.

Next article will start dealing with the amateur satellite tracking stations operated in South Africa during the period 1957 to the present.

Naval Hill Planetarium

Bosman Olivier

The traditional 'City of Roses' and judicial capital of South Africa, Bloemfontein, is set to become famous for another reason – the first digital planetarium in sub-Saharan Africa. This is now, besides the roses, a must visit city. Any traveller in South Africa who misses this new digital planetarium will be doing him or herself a great disservice. It is even worth a detour along the road between Cape Town and Gauteng.

Situated on top of Naval Hill, with its splendid view over the Free State provincial capital is the old Lamont-Hussey Observatory. This was the first of a number of observatories established all over the world by die University of Michigan in the USA, to assist their astronomers in their studies of the Universe. During its active life between 1928 and 1953 its 27” refractor helped discover some 5 590 double stars. Although it was closed in 1953, it was reopened in 1963 until 1972 when it was finally closed and some of the equipment was returned to the University of Michigan in Ann Arbor, Michigan. The rest stayed on in South Africa. Since then the building was utilised as a theatre, amongst other things.

The dream

In the mid 1990's Prof Matie Hoffman, current president of ASSA, planted the seed of a digital planetarium in Bloemfontein. With the help of numerous colleagues and organisations including the Mangaung Metro Municipality (MMM), the Free State Department of Economic Development, Tourism and Environmental Affairs (DETEA), the University of the Free State (UFS) developed the concept for the planetarium project. The University will also be responsible for the operation and further funding of the planetarium.

Fig 1. *Matie Hoffman at the opening.*

Some R13 million has already been spent on the project which will eventually establish a Centre for Earth and Space. To bring this project to fulfilment, another R15 million is required.

The doors to the new planetarium were officially opened on 1 November 2013 during a gala ceremony at which the Deputy Minister for Science and Technology, Adv. Michael Masutha, delivered the opening address. In his speech he painted a picture of South Africa moving from an underdeveloped country to a developed country. “Man came from Africa and it is befitting that Africa hosts major scientific programmes such as the SKA”, he said. We should also stop talking about a knowledge economy but rather speak about a celestial economy. South Africans should rediscover themselves as humans, he said.

Fig 2. *Opening day.*

In his welcoming address, the chancellor of the UFS, Dr Khotso Mokhele, said the university was proud to be part of this exciting development. He added that the planetarium was the first component in the proposed Centre for Earth and Space. When completed the centre will be a multi-purpose facility hosing the planetarium and an Environmental Education

Centre and a Science and Arts garden. The planetarium will also become a resource or model for other organisations wishing to establish similar facilities, Dr Mokhele said.

Prof Nicky Morgan, Vice Rector of the UFS, explained the University's commitment to be a partner in education. He expressed the hope that this facility will become the training ground for many students and school children through its educational programmes.

The dome and projectors

The University of the Free State (UFS) is the first in the world to boast a modern digital planetarium which was erected within an existing observatory. "What makes the project unique is the fact that we converted the existing observatory structure into a modern digital planetarium. It hasn't been done anywhere else," says Andrew Johnson, engineer at Sky-Skan, the company supplying and installing the equipment. Andrew has worked on similar projects, with his company installing digital planetariums around the world. He spent several weeks in Bloemfontein working with local technicians and staff to set everything up. The digital dome that was fitted into the existing observatory structure, is a 12-metre seamless aluminium screen complemented by a powerful surround-sound system and multiple data projectors from Sky-Skan. This results in an immersive experience of the digital universe, as well as the recreation of the macro and micro cosmos and a variety of other environments.

This particular dome arrived in Bloemfontein in June 2013, after being shipped to South Africa in a disassembled state. Reconstructing the aluminium dome inside the observatory dome was a mammoth task, requiring some 20 000 pop rivets to keep everything in place. The individual panels were attached in sections to the ribs, thus forming a smooth concave shell which will be the surface for the projection system. After this the two specialised projectors were installed, each sporting a fish-eye lens that had to be made especially for the system at a price tag of R40 000 per lens.

"It was not all smooth sailing," says Andrew Johnson. "When we first started testing the system and setting it up, we discovered that the dome was some 400 mm too high for the projection system! This meant that it had to be lowered and for that task we had to call in mining engineers from Welkom to assist us," says Johnson. Despite an accident on the scene, when a chain broke loose and hit a worker on the head, forcing him to hospital, he was, however, back the very next day to help complete the job on time.

Fig 3. *The computers than run the planetarium*

The projection system is data and power hungry. Each of the two projectors is run by a bank of four computers, each with 2.25 TB of hard disk space. In all, the planetarium requires some 200 kW of electricity to run the digital hardware and air conditioning, and all the other electrical appliances used in the planetarium.

What makes a digital planetarium so special is the fact that it offers visitors an inclusive experience. Previously visitors could only watch projected stars and constellations, but with the digital planetarium they can now experience a journey through space which feels very close to reality. Andrew points out that, apart from stargazing and travelling through space, the digital planetarium allows the audience to visit planets, explore the secrets of the oceans or even organs in the human body.

The planetarium auditorium can seat approximately 90 adults or 120 children, will also be used for concerts, state-of-the-art presentations, theatre productions, as well as meetings, conferences and exhibitions, according to prof. Hofmann.

The partners

Besides the University of the Free State, the local, provincial and national government, a number of organisations assisted financially and or otherwise to get the project off the ground. These include the American Museum of Natural History, the University of Michigan, the Hermann Olthaver Trust, Joan St Leger Lindberg Charitable Trust, the Old Mutual Foundation, the Raubex Group and Windmill CSI (Sun International).

In a letter to the Rector and Vice Chancellor of the UFS, Prof JD Jansen, and the president of the University of Michigan, Mary Sue Coleman, wrote: “We are delighted to see the former University of Michigan Lamont-Hussey Observatory being transformed into the first digital planetarium in sub-Saharan Africa. During the observatory's use as a research facility, University of Michigan astronomers travelled to South Africa to study starlight entering the Observatory from the cosmos. Now a digital planetarium will provide the starlight from inside the Observatory, and bring the excitement of modern astronomy and other sciences to a very broad audience.” “We offer our congratulations to everyone involved in this achievement, and look forward to exploring additional collaborative efforts with South Africa, particularly in the areas of science, engineering, and math,” she concluded.

In a letter, Prof. Michael Shara, Curator of Astrophysics at the American Museum of Natural Science and chairman of the board of the Southern African Large Telescope, said: “One of the most compelling reasons for the American Museum of Natural History to have joined the SALT consortium more than five years ago, was to enable us to contribute to science outreach and education in South Africa. AMNH pledged, at the time, that if a digital planetarium were built in this country, then we would supply, free of charge, the content. I am delighted that this has finally happened, here in Bloemfontein.” He added that analogue space shows provide lovely, simulated, views of the night sky from different places on Earth.

Fig 4. *Students taking part in an astro quiz.*

Digital shows allow astronomers to transport you out into the solar system, to the stars, nearby galaxies, and distant reaches of the universe. Each AMNH space show requires the efforts of over 50 people working for two years, he says. Astrophysicists are involved at every step to make sure that audiences see the latest astrophysics research. Every star the audience sees in each space show, in 3 dimensional space, is seen where it really is. “Despite all the great science, we should never forget that the stars and the night sky are beautiful,” Shara says in his letter. “But please also take a few minutes to enjoy the free spectacle that nature provides – the stars – overhead every night.”
(All images by the author).

Colloquia and Seminars

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

Also included in this section are the colloquia/seminars at the SAAO, UWC and the Astrophysics, Cosmology and Gravity Centre at UCT, ACGC. Also included are the SAAO Astro-coffees which are 15-20min informal discussions on just about any topic including but not limited to: recent astro-ph papers, seminal/classic publications, education/outreach ideas and initiatives, preliminary results, student progress reports, conference/workshop feedback and skills-transfer.

Editor

SAAO

Title: Circumstellar environments of massive stars
Speaker: Jonathan Mackey (Argelander Institute for Astronomy, Bonn)
Date: 13 February
Time: 11h00 – 12h00
Venue: SAAO Auditorium

Abstract: Massive stars drive strong winds and emit ionising radiation which dramatically alters their surroundings. At least 25 per cent of them become runaway stars, travelling supersonically through the interstellar medium. For these stars, their circumstellar interaction usually relaxes to a stationary state faster than the star evolves, making comparison between theory and observations much simpler. Cool red supergiants like Betelgeuse have slow dense winds, and our numerical simulations suggest that Betelgeuse's bow shock is very young and may still be expanding. A model in which the star evolved recently from a blue supergiant can successfully explain many (but not all) of the observational constraints. Younger, hot stars like Zeta Ophiuchi also emit ionizing radiation that heats their surroundings. Radiation-hydrodynamics simulations show that the dynamical impact of photoionization heating on the interstellar medium can be much larger than that of wind-driven bow shocks.

Title: Rotation, activity and stellar oscillations in Vega? Results of high precision velocimetry with SOPHIE/OHP
Speaker: Torsten Böhm
Venue: SAAO Auditorium
Date: 6 March
Time: 11h00 – 12h00

Abstract: The rapidly rotating standard Ae star Vega has been observed during 5 nights with the highly stabilized velocimeter/spectrograph Sophie at OHP/ France. New insights on stellar oscillations in that category of stars have been searched for and are presented in that presentation. The detailed study of photospheric lines variations enabled us to conclude on the stellar rotation period, providing a direct answer to a longlasting polemics between spectroscopists and interferometrists. I will finish the talk with a presentation of the Neo-Narval project, a highly radial velocity stabilised spectropolarmeter.

Visitors from neighbouring African astronomy communities in Namibia, Ethiopia and Zambia who are visiting the Office for Astronomy Development, this week. This special colloquium will be an hour long and made up of three 20 minute talks in the following order:

Title: Kyoto University 3.8-m Telescope project at Okayama
Speaker: Tetsuya Nagata
Date: 20 March
Time: 11h00 – 12h00
Venue: SAAO Auditorium

Abstract: Kyoto University has been constructing a 3.8-m telescope of 18 petal-shaped segment mirrors, with an ultra-light-weight mounting; the mirrors are produced with high-precision grinding. It is to be located at the Okayama Astrophysical Observatory (of National Astronomical Observatory, Japan) site, where a younger 1.88-m telescope (than the one at Sutherland) was placed in 1960. Its main objectives are time-domain

astronomy and direct imaging of exo-planets with extreme adaptive optics. We launched the project in 2006, and a variety of technical developments have been executed since then, on a private fund. The upper part of the ultra-light-weight mounting was constructed in 2010; some of you might have seen it in the "10 years of IRSF" conference at Nagoya University. We have succeeded this year in getting government budget for the completion of the telescope. The configuration construction is completed in 2015. It is to be the hub of the seven-university collaboration "OISTER (Optical and Infrared Synergetic Telescopes for Education and Research)", which IRSF belongs to, and will be opened for the astronomers over Japan, and the world, in 2018

Title: Assembly of stellar mass in cluster cores since z=1
Speaker: Claire Burke
Date: 3 April
Time: 11:00
Venue: SAAO Auditorium

Abstract: The formation and evolution of brightest cluster galaxies (BCGs) is a topic of much recent debate in both observational and theoretical studies, with a range of evolutionary scenarios being reported by observes and striking disagreements being found between simulated and observed BCG properties. For example, some observational studies report no growth in mass for BCGs since z=1 whilst others find a doubling in mass over this time, for the same timescale simulations predict up to a quadrupling in mass of these galaxies. Complementary to these results, it has recently become clear that the stars found in the diffuse intracluster light (ICL) form a major component of cluster stellar mass and its evolution is linked very closely with that of BCGs. Currently the general consensus is that the ICL has grown and evolved significantly, increasing in terms of its contribution to the total cluster light by more than a factor of 4 since z=1, however the mechanisms responsible for this remain unclear. I will present the results of our recent study of mergers in BCGs and the build-up of the ICL since z=1 using deep multi-wavelength data from the CLASH survey. We find surprising new evidence for very little growth of the ICL and BCG, with very few mergers taking place in cluster cores.

ACGC

Title: Measuring the transition to homogeneity with photometric redshift surveys
Speaker: David Alonso (Astrophysics, University of Oxford - UK)
Venue: M111 Maths Building, UCT
Date: 18 February
Time: 12h00

Abstract: One of the fundamental premises of modern cosmology is the so-called Cosmological Principle (CP): the assumption that on sufficiently large scales the Universe is statistically homogeneous and isotropic. The validity of the CP is a long standing question in cosmology, and has been challenged by different alternative cosmological models. One possibility is that the growth of structure via gravitational collapse has spoiled homogeneity at late times, and that the distribution of galaxies is better described as a multi-fractal. In these models structure is found hierarchically on all scales and homogeneity is never reached, therefore FRW would no longer be a valid description of the Universe. A clean observable that characterizes these models is the fractal dimension, whose unbiased measurement requires enormous volumes and a careful treatment of survey boundaries. I will discuss the possibility of measuring the transition to homogeneity (or lack thereof) in an alternative way using photometric redshift surveys such as the Dark Energy Survey.

Title: Detecting Particle Dark Matter Signatures by Cross-Correlating Gamma-Ray Anisotropies and Cosmic Shear
Speaker: Stefano Camera (Instituto Superior Técnico - CENTRA - Universidade de Lisboa - Portugal)
Venue: M111 Maths Building
Date: 26 February
Time: 12h00

Abstract: Both gravitational lensing and cosmological gamma-ray emission stem from the presence of dark matter (DM) in the universe. Indeed DM structures are responsible for the bending of light due to the gravitational lensing effect, and those same objects can emit gamma rays, either because they host astrophysical sources (active galactic nuclei or star-forming galaxies) or directly by DM annihilations/decays. Such gamma rays should therefore exhibit strong correlation with the gravitational lensing signal, correlation that can provide novel information on the composition of the extragalactic gamma-ray background. If the DM contribution to the EGB is significant enough, although compatible with current observational bounds, its strong correlation with gravitational lensing makes such signal potentially detectable by combining forthcoming experiments.

Title: 21cm Intensity Mapping
Speaker: Tzu-Ching Chang (ASIAA
Venue: M320 (UCT, Maths Building).
Date: 27 February
Time: 13h00

Abstract: The redshifted 21-cm emission from neutral hydrogen has emerged as a powerful probe for large-scale structure; a significant fraction of the observable universe can be mapped in the intensity mapping regime out to high redshifts. At redshifts around unity, the 21-cm emission traces the matter distribution and can be used to measure the Bary on Acoustic Oscillation (BAO) signature and constrain dark energy properties. I will describe our on-going observing program at the Green

Bank Telescope (GBT), aiming to measure the 21cm power spectrum at z=0.8. A 800-MHz multi-beam focal-plane array for the GBT is currently under construction in order to facilitate a large-scale survey for BAO and the redshift-space distortion measurement for cosmological constraints. I will also describe spectral line Intensity Mapping in general, and how one can use CO and [CII] Intensity Mapping to help constrain reionization processes at 6<z<9, along with information from 21cm fluctuation measurements at the Epoch of Reionization.

Title: Cosmic Variance limited BAO from the DEUS-FUR simulation
Speaker**:** Vincent Bouillot (UCT)
Venue: M111 (UCT, Maths Building).
Date: 4 March
Time: 12h00

Abstract: We investigate the non-linear evolution of baryonic acoustic oscillations in the low redshift matter power spectrum from the DEUS-FUR cos mologica l simulation, first N-body simulation encompassing the full observable cosmic volume. This simulation thus gives cosmic variance limited measurements at the BAO scale. In this talk, I will first discuss the statistical and systematic errors on the measurement of the power spectrum and then talk about the non-linear evolution of BAO. Finally, I will explain the method used to characterize the BAO pattern and give some valuable results on the theoretical modelling of the BAO.

Title: How to feed and care for your supermassive black hole
Speaker: Romeel Davé
Venue: M320 (UCT, Maths Building)
Date: 6 March
Time: 13h00

Abstract: The early emergence of central supermassive black holes and their correlation with host galaxy properties remains one of the major unsolved problems in astronomy. In the past decade there has been great progress on including black holes, and associated feedback processes, into cosmologically-based models of galaxy formation. Most of these have been based on the principle of Bondi accretion, with the associated feedback carefully tuned to match the observed relation between galaxy bulge mass and black hole mass. I will discuss a new scenario to grow black holes, based on the idea of secular instabilities in galaxy disks that dissipate torque. Using high-resolution zoom hydrodynamical simulations, I will show how such torque-limited accretion provides a more natural and straightforward explanation for early black hole growth as well as late-time scaling relations, and discuss how the latest Hubble observations of active black holes support this scenario. If correct, our models provide new insights into the evolution of supermassive black holes and their impact on their host galaxies across cosmic time.

Title: A challenge to cosmic no-hair conjecture
Speaker**:** Pr. Jiro Soda (Kobe University - Japan)
Venue: M111 (UCT, Maths Building).
Date: 11 March
Time:12h00

Abstract: The cosmic no-hair conjecture has survived for a long time in spite that many people tried to find a counter example. In this talk, I will provide simple counter examples to the cosmic no-hair conjecture found for the first time by Watanabe, Kanno & Soda. I will also discuss possible cosmological implications.

Title: Analogue Transformations in Physics and their Application to Acoustics
Speaker**:** Sante Carloni (Institute for Theoretical Physics - Prague)
Venue: M111 (UCT, Maths Building).
Date: 13 March
Time: 12h00

Abstract: In this talk I will present a nonstandard application of general relativity related to the field of material science. Exploiting the invariance under diffeomorphisms of general relativistic equations one can define “transformation techniques” that can be used to design new types of metamaterials. This approach works very well with electromagnetic metamaterials, but it is not very successful in other fields. However, using the concept of analogue gravity this limitation can be overcome. In the talk I will introduce a general transformation technique which could be considered as a new paradigm for controlling wave propagation in different branches of physics, from acoustics to quantum fluids to graphene electronics. As an application, I will derive a ''transformation acoustics” formalism that allows the design of devices which were impossible in the standard approach. Some specific examples will be given.

Title: From configuration to dynamics - Emergence of time in classical field theory
Speaker: Jean-Philippe Uzan (Institut d'Astrophysique of Paris - France)
Venue: M111 (UCT, Maths Building).
Date: 18 March
Time: 12h00

Abstract: In standard field theory, the relativistic notion of causality, inherited from special relativity, is implemented by considering a Lorentzian metric. I will investigate the possibility that at the microscopic level the metric is Riemannian and that the Lorentzian structure is an emergent property. The mechanism will first be illustrated on scalar, vector and spinor fields in flat space-time and I will then show that gravity can also be included. In that case the theory for the effective Lorentzian metric is not general relativity but of the Galilean type. I will discuss the constraints that arise from the stability of the theory and the equivalence principle, as well as the theoretical limits of such an approach.

Title: What can radio-telescopes do for cosmology?
Speaker: Mario Santos (UWC)
Venue: M320 (UCT, Maths Building)
Date: 20 March
Time: 13h00

Abstract: A new generation of radio telescopes is being developed with high sensitivity and large fields of view, making them exquisite "machines" for cosmology. They will provide all sky surveys will large numbers of radio galaxies both in continuum and in HI as well as large sky intensity maps of the HI signal up to high redshifts. This in turn will allow stringent constraints not only on "standard" cosmological parameters, such as dark energy, but also beyond that, such as primordial non-Gaussianity, modified gravity or other effects on ultra-large scales. I will review the surveys and cosmological probes we can expect from these telescopes, including MeerKAT and SKA1-Mid to be built in South Africa.

Title: Symmetries of the Universe: The Copernican Principle and its constraints
Speaker: Wessel Valkenburg (Leiden Institute of Physics - the Netherlands)
Venue: M111 (UCT, Maths Building).
Date: 24 March
Time: 12h00

Abstract: The Friedmann-Lemaître metric has a high degree of symmetry, both translational and rotational. The Copernican Principle is the reason why we assume these symmetries. So far, the Copernican Principle had never been tested on cosmological scales. I show the first quantitative test of the Copernican Principle. As a by-product, we find the impact of cosmic structure on our perception of the Friedmann-Lemaître metric. Both the equation of state of Dark Energy and the local expansion rate are more uncertain than we thought, when we take into account that we live at any specific place in the universe that is not exactly homogeneous. Finally, I briefly discuss how other symmetries of space and time could be tested.

Title: Remapped dark-matter haloes and cosmological peculiar velocities
Speaker: John Peacock (Institute for Astronomy, University of Edinburgh, UK)
Venue: M111 (UCT, Maths Building).
Date: 1 April
Time: 12h00

Abstract: A recent dominant theme in cosmology has been the use of galaxy redshift surveys to measure the effects of peculiar velocities, yielding a measurement of the rate of growth of cosmic structure and hence a knowledge of the strength of gravity on 10-100 Mpc scales. This talk will review the constraints of this kind arising from the GAMA and VIPERS surveys. In order to interpret the results, we must consider the relation between galaxies and dark matter, which requires the ability to predict the distribution of dark-matter haloes for many different cosmologies. Direct simulation is too slow for this task, and we discuss a new method that allows rapid generation of the required halo catalogues, starting from a single high-resolution simulation.

UWC

Title: Measuring the transition to homogeneity with photometric redshift surveys
Speaker: David Alonso (Oxford)
Venue: Room 1.35 of the Physics Department, UWC
Date: 14th February
Time: 14h00

Abstract: One of the fundamental premises of modern cosmology is the so-called Cosmological Principle (CP): the assumption that on sufficiently large scales the Universe is statistically homogeneous and isotropic. The validity of the CP is a long standing question in cosmology, and has been challenged by different alternative cosmological models. One possibility is that the growth of structure via gravitational collapse has spoiled homogeneity at late times, and that the Friedmann-Robertson-Walker metric is no longer a valid description of the Universe. In these fractal models, structure is found hierarchycally on all scales and homogeneity is never reached. A clean observable that characterizes these model is the fractal dimension, whose unbiased measurement requires enormous volumes and a careful treatment of survey boundaries. I will discuss the possibility of measuring the transition to homogeneity (or lack thereof) in an alternative way using photometric redshift surveys such as the Dark Energy Survey

Title: Cosmology on Ultralarge Scales with Intensity Mapping of Neutral Hydrogen Emission - Pushing the Limits on Primordial Non-Gaussianity
Speaker: Stefano Camera (CENTRA)
Venue: Room 1.35 of the Physics Department, UWC
Date: 28 February
Time: 14h00

Abstract: The large-scale structure of the Universe supplies crucial information about the physical processes at play at early times. Unresolved maps of the intensity of 21 cm emission from neutral hydrogen, HI, at redshifts $1<z<5$ are the best hope of accessing the ultra large-scale information, directly related to the early Universe. A purpose built HI intensity experiment may be used to detect the large scale effects of primordial non-Gaussianity, placing stringent bounds on different models of inflation. We argue that it may be possible to place tight constraints on the non-Gaussianity parameter, fNL, with an error close to 1.

AIMS

Title : General Relativistic N-body simulations
Speaker: Martin Kunz (Institute for Theoretical Physics, University of Geneva).
Venue: AIMS research centre
Date: 24 February,
Time: 12h00.

Abstract: Non-linear clustering in cosmology is usually investigated with the help of Newtonian N-body simulations. We know however that we should really use General Relativity, and that Newtonian physics misses important ingredients like anisotropic stress, the hallmark of modified gravity models, or the possibility of so-called backreaction. Unfortunately a fully general GR simulation is numerically too demanding. In my talk (based on arXiv:1308.6524 and arXiv:1401.3634) I will give an informal overview of how we can circumvent this problem while still retaining the cosmological relevant features of GR, and show some early results for plane-symmetric universes.

Title: Uncertainty Relations in QFT and Classicalization
Speaker: Alexander Vikman (New York University (NYU), Department of Physics, centre for Cosmology and Particle Physics (CCPP))
Venue: AIMS research centre
Date: 25 February
Time: 12h00

Abstract: Following my recent paper arXiv:1208.3647, I will start by reviewing one of the cornerstones of quantum mechanics - uncertainty relations. Further, I will formulate the uncertainty relations in QFT. Then I will discuss vacuum quantum fluctuations of simple Nambu-Goldstone bosons - derivatively coupled single scalar-field theories possessing shift-symmetry in field space. I will argue that quantum fluctuations of the

interacting field can be drastically suppressed with respect to the free-field case. Moreover, the power-spectrum of these fluctuations can soften to become red for sufficiently small scales. For the recently introduced classicalization, I will demonstrate that this suppression can only occur for those theories that admit such classical static backgrounds around which small perturbations propagate faster than light. Thus a quasi-classical softening of quantum fluctuations is only possible for theories which classicalize instead of having a usual Lorentz invariant and local Wilsonian UV-completion. I will illustrate this analysis by estimating the quantum fluctuations for the DBI-like theories.

Title: "Reconstructing the Mass Assembly of Galaxy Disks over the last 7 Billion Years with ALMA, HST and Spitzer"
Speaker: Kartik Seth National Radio Astronomy Observatory (NRAO).
Venue: AIMS Research Center
Date: 14 March
Time: 12h00

Abstract: Bars are a key signpost in the evolutionary history of a disk galaxy. When a disk is sufficiently massive, dynamically cold and rotationally supported, and sufficient time has elapsed for the baryonic matter to exchange energy and angular momentum with the dark matter halo or the outer disk, the formation of a bar is inevitable. Therefore understanding the evolution of the bar fraction as a function of the host galaxy properties and as a function of redshift provides important clues to the evolutionary history of galaxies. I will present the latest results on local bars from the Spitzer Survey of Stellar Structure in Galaxies (S4G) and discuss the observations for the declining bar fraction with redshift from the COSMOS survey. A plausible reason for the decline in the bar fraction may be that galaxy disks were too dynamically hot to host bars at higher redshift which we have investigated using the DEEP2 / AEGIS data. Together these data are beginning to provide a coherent and consistent picture for the assembly history of disks on the Hubble sequence. The star formation in these disks is also now being understood with the latest

results from ALMA. I will show the latest results on the cosmological evolution of the molecular gas content in a mass-selected sample of galaxies at three epochs, z=2.2, z=1, and z=0.3 and discuss planned Cycle 1 observations of the molecular gas environment in the prototypical barred spiral NGC 1097.

Title : Modelling cosmological reionization and IGM temperature evolution

Speaker: Sourav Mitra (University of Western cape, Postdoctoral fellow)
Venue: AIMS research centre
Date: 14 April
Time: 12h00

Abstract : Reionization is a complex process whereby hydrogen (and helium) in the Universe is ionized by the radiation from first luminous sources. Theoretically, the importance of the reionization lies in its close coupling with the formation of first cosmic structures and hence there is considerable effort in modelling the process. In this talk, I will present our recent works on some aspects of this subject. In particular, I will give an overview of a semi-analytic approach to study the observational constraints on reionization. We implement a method to do a detailed statistical analysis using Principal Component Analysis (PCA) technique. I will also discuss different observational aspects on this area of research and show how reionization can affect the IGM temperature evolution.

Deep-Sky Delights: The Lion roars tonight

Magda Streicher

The constellation Leo possesses a measure of dignity and justifiably reflects a true mental picture of the animal it has been named after. In nature the lion is regarded as the king of the animal kingdom, so the presence of a lion constellation should not be an unusual idea. The image itself is easily recognisable and in some ways brings to mind the lion image found in Egyptian records. From the southern skies the image is seen upside down, but that should not deter us from admiring it, as the objects (mainly galaxies) found within the constellation, bring ample reward.

Leo is one of the original Greek constellations representing one of the twelve labours of Hercules. As we look out from the plane of our Milky Way, the con-stellation is host to many galaxies, but there are also a few surprises which make a visit to this celestial animal very inte-resting.

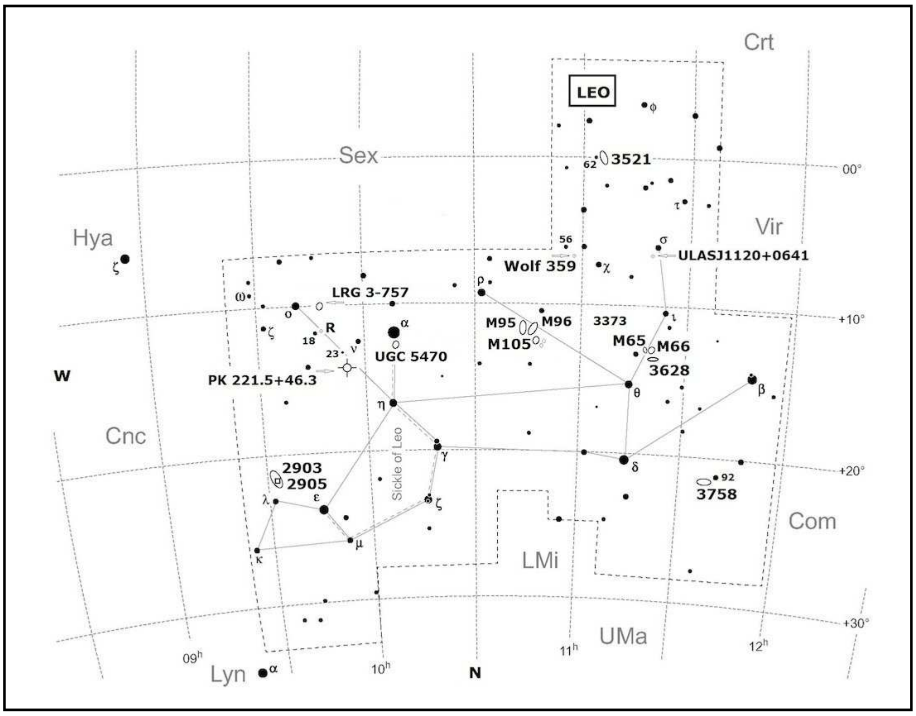

Fig 1. *The constellation Leo and surrounds.*

The constellation is also famous for the ecliptic that runs through it just south of magnitude 1.4 alpha Leonis, better known as the star Regulus. The planets Venus and Jupiter, in presumably towards the western part of the constellation, appeared to fuse together to look like one object, during a conjunction in 2 BCE, a sight no one alive had ever seen. Regulus is the 21st brightest star and shines with a super-brilliant white colour 75 light years away. It is also a multiple system with a white dwarf companion orbiting it every 40 days. Regulus, referred to as the heart star, represents the front paw of the lion, and is situated at the western base of the well-known Leo sickle asterism.

The faint galaxy **UGC 5470** (Leo 1) is situated only 28' north-west of Regulus. Leo I is a dwarf spheroidal galaxy discovered in 1950 by Albert George Wilson on a photographic plate taken with the 48-inch Schmidt camera at Palomar Observatory. Although the galaxy is not all that faint, it is almost impossible to spot in the overwhelming glare of Regulus, which is about 10 000 times brighter, and on top of that the dwarf is a staggering 800 000 light years further away. After trying my uttermost best putting Regulus out of the field of view I suspected only a soft haze with averted vision. However, there is a nice asterism of stars to appreciate that forms a triangle with Regulus and the galaxy in the same field of view.

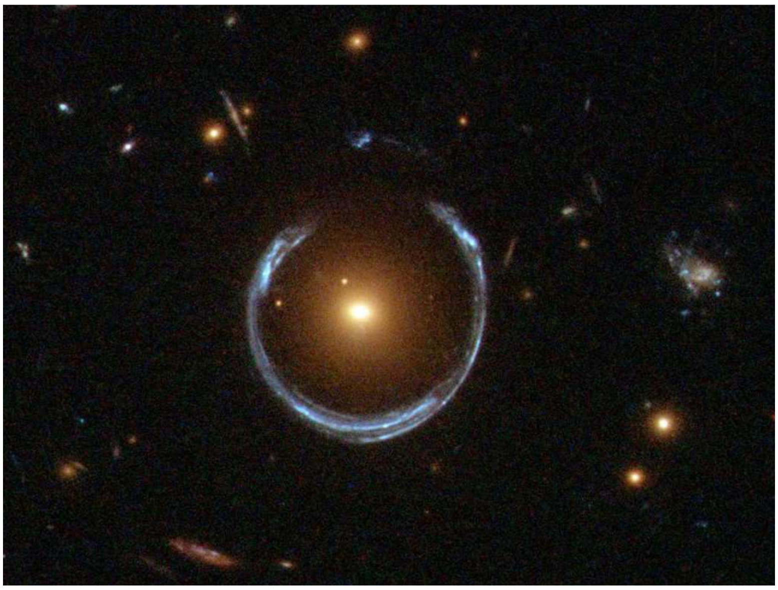

Fig 2. *Einstein Ring in Leo*.

Then a very special object named **LRG 3-757**, is an Einstein Ring discovered in 2007 south-west of Regulus and one degree east of magnitude 3.5 omicron Leonis. It is the deformation of the light from a luminous red galaxy into a ring through gravitational lensing of the source's light by an object with an extremely large mass, which occurs when the source, lens and observer are all aligned. Do visit the spot, but, well, if all fails there is a very nice reddish star of magnitude 6.8 (HD

84418) north-west and a yellow-coloured double star just east of Einstein's galaxy that is sometime refer to as the "Cosmic Horseshoe"

A degree further north is the star **R Leonis**, the first long-period Mira-type to be discovered, in the year 1782, about 600 light years away. It varies from a maximum brightness of 4.3 to 11.6 over a period of 312 days. The estimated magnitude was found to be around 8+ on the night of 26 February 2014, shining with a nice orange to red colour.

The very faint planetary nebula **PK 221.5+46.3** discovered west of Regulus by Ellis Grayson Bond from Palomar Sky Survey Prints is situated nearly a degree north of the star 23 Leonis. It is a large nebula with a low surface brightness and as suspected there were just no trace of it. The nebula is about 1 500 light years distant with a very hot white dwarf star, with the suggestion that this star could be a binary. Sadly, the nebula can be appreciated only through the eye of Hubble.

The sickle asterism is quite obvious, and although upside down for us down south it can be seen as comprising a few bright stars. North of Regulus is the magnitude 3.4 eta, an A-type supergiant star 2 000 light years away. Further north is the double star gamma, which also has the faint galaxy NGC 3123 as a close neighbour just 20' towards the south-east. Towards the bend is the magnitude 3.4 zeta Leonis, then the red-coloured magnitude 3.8 mu Leonis, and towards the west-end of the sickle, is the magnitude 2.9 epsilon Leonis.

A galaxy with a twist is **NGC 2903**, situated about 3.8 degrees south-west of epsilon Leonis. The constellation is strewn with galaxies, so believe me when I say it would be a very good idea to have a detailed star chart at hand to make identification easier. NGC 2903 is a barred spiral galaxy discovered by William Herschel, who catalogued it on 16 November, 1784. It is a soft oval in a north-east to south-west direction, somewhat larger than average and not too faint to appreciate. The challenge, however, is to spot the small hazy spot **NGC 2905** inside the flimsy northern edge of

NGC 2903. The northern part appears slightly thicker to me but I would love to have feedback on this object, so please have a look and let me or Auke Slotegraaf, our deep-sky director, know.

Probably one of the most concentrated groups of galaxies can be seen squeezing up close to one another all along the long slender body of the Lion figure. Halfway between Regulus and magnitude 3.3 is theta Leonis, a well-known group of three galaxies which has been observed by many. **Messier 105** (NGC 3379) is an elliptical giant galaxy discovered by Pierre Mechain, who also discovered the nearby galaxies Messier 95 (NGC 3351) and Messier 96 (NGC 3368) in 1781. M105 displays a large bright glow with an even surface brightness. With higher magnification it grows slowly brighter towards a tiny nucleus. The northernmost galaxy 6' towards north-east is **NGC 3384**, an elongated spiral in a north-east to south-west direction with an outstanding bright, nearly stellar nucleus. The third member of the group towards the south of M105 is **NGC 3389**, which can only be described as faint and round, not at all easy to spot, although deep photographs show a mottled centre with the loosely spiral arms.

Only a degree further south-west are two galaxies, **Messier 95** (NGC 3351) and **Messier 96** (NGC 3368), situated only 40' apart. M95 is not very bright, but one can glimpse it as a quite round soft glow with a halo around it, brightening to a sudden oval nucleus. With very high magnification slender hazy parts can be seen on the sides of the nucleus which could well be dedicated spiral arms, but dark skies are essential. M96 is a beautiful, large bright galaxy, and with high power extending into a sudden bright nucleus. The galaxy also displays a soft halo, slight grainy, and covered in haze. A dusty section could be glimpsed more so to the south-western part of the galaxy. The much talked about but disappointing comet C/2012S1 was discovered by ISON (International Scientific Optical Network) beyond the orbit of Jupiter. On 21 September 2012 it was just a stone's throw away from these galaxies in late October 2013. If the comet should reach the status of a "very bright comet", as predicted, it could make a great picture to remember.

Fig 3. *M65 and M66, part of the Leo Triplet (Dale Liebenberg).*

The tail-end star is beta Leonis, better known as Denebola, (it literally means “tail of the Lion”), an A3-type star similar to alpha Canis Major (Sirius) and about 40 light years away. It is no easy task to scan and observe the area south of the Lion’s “tail” – the number of galaxies there are like the hair on a lion’s back so to speak. But easy enough to find is the trio of galaxies **Messier 65** (NGC 3623), **Messier 66** (NGC 3627) and **NGC 3628**, situated about halfway between theta and iota Leonis.

The group is also known as the Leo Triplet and is about 30 million light years away. M65, the western member of the trio, is a typical elongated spiral extended in a north to south oval. Higher magnification brings out a diffused, knotted, uneven appearance with a bright nucleus and diffuse halo. M66, situated 20’ towards the east, is the brightest member, with an uneven light-spread over the large surface. It displays a soft outer edge that fades towards an attractive, bright, large elongated nucleus. Some observers claim to see an extension that gives the galaxy a sort of gentle curve. However, some deep photographs show that the southern spiral arm is slightly displaced. NGC 3628 lies just 35’ north of M66 and appears needle-thin with its light spread softly over the whole surface. Careful observation brings to the fore a faint elongated nucleus situated in an east-west direction. The trick here is to spot the faint dust lane that cuts through the lower southern part of the galaxy. Classed as one of the flattest galaxies in the sky, and famously known as “King Hamlet’s Ghost” Galaxy. To appreciate this galaxy best, have a look at the beautiful Hubble picture of it, but do not neglect your own observation through an ordinary telescope if there is a chance make one.

Between magnitude 4 sigma Leonis and the galaxy NGC 3624 is the home of the quasar **ULAS J1120+0641**. According to a paper published in *Nature* on 6 December 2012 it is one of the most distant quasars and contains no heavy elements. The active galaxy is 13.3 billion light years away gives us a glimpse into what the universe was like about 700 million years after the Big Bang. According to the evidence the galaxy is made up almost entirely of hydrogen that has not yet become stars. It is the first time astronomers have seen a galaxy so young that its gas has not yet collapsed into stars (*Astronomy*, April 2013). ULAS J1120+0641 were discovered by the Infrared Deep Sky Survey, using the UK Infrared Telescope located in Hawaii.

Fig 4. *Starfield around Wolf 359.*

The Leo constellation is also home to **Wolf 359**, the third closest star to our solar system after the alpha Centaurus group and Barnard's star situated 48' north of the star 56 Leonis. It has been classified as a cool M-type dwarf star with a magnitude of 13.5 only 7.7 light years away. The star is one of the faintest and lowest-mass stars known and relatively young, with an age of less than a billion years, and moves about 4.7" per year. It was fairly easy to locate three more or less 13 magnitude stars in a row north of star 56 Leonis with high power. Map work afterwards proved that the middle star to be Wolf 359. Maximilian Franz Joseph Cornelius Wolf (1863-1932) discovered this nearby star in 1918. He was a German astronomer and a pioneer in the field of astrophotography, chairman of Astronomy at the University of Heidelberg and Director of the Landessternwarte Heidelberg-Königstuhl observatory from 1902 to 1932.

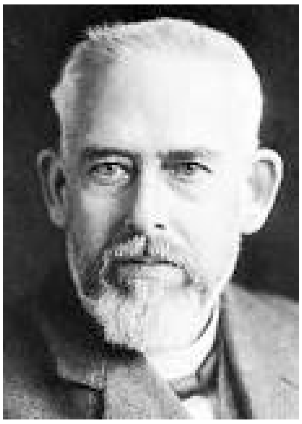

Fig 5. *Franz Joseph Wolf.*

The galaxy **NGC 3521** is taking control of the far southern part of the constellation and is just 33' east of 62 Leonis. First impression shows the galaxy as relatively bright in a slightly elongated north-south direction. High magnification brings to the fore a large bright nucleus with a hazy envelope that fades out towards the edge.

Fig 6. *The Galaxy NGC 3521 in Leo (Dale Liebenberg).*

Riding along on the Lion's tail, close to the eastern border is an especially rare type of galaxy, **NGC 3758**, only one degree west of 92 Leonis. Strange but true, astronomers discovered two active super-massive black holes in NGC 3758 (Markarian 739), which is about 425 million light years away. What is amazing is that 11 000 light years separate the two cores, each of which contains a black hole. It is a known fact that massive galaxies have black holes at their cores, but to find two of them both feeding on nearby material and spewing out high-energy radiation is extraordinary. News of the discovery, led by Michael Koss of the University of Maryland, College Park, appeared in the *Astrophysical Journal Letters*.

In nature the lion has a mighty roar – and it is entitled to it! And as you can see, its heavenly counterpart, the constellation Leo, equally has more than enough reason to make its presence boldly and loudly known.

NAME	OBJECT	RA	DEC	MAG	SIZE
NGC 2903	Galaxy	09h32m.2	+21°30'.8	9.7	12.6'x6'
LRG 3-757 Einstein Ring	Galaxy	09h46m.8	+10°06'.9	-	-
R Leonis	Mira *	09h47m.5	+11°25'.7	4.4 11.3	-
PK 221.5+46.3	Planetary Nebula	09h53m.0	+13°44'.8	13	720"
UGC 5470 Leo I	Galaxy Dwarf	10h08m.4	+12°18'.5	10.2	9.8'x7.4'
NGC 3351 M95	Galaxy barred	10h43m.9	+11°42'.1	10.6	7.3'x4.4'
NGC 3368 M96	Galaxy Spiral	10h46m.7	+11°49'.1	9.8	7.8'x5.2'
NGC 3379 M105	Galaxy elliptical	10h47m.8	+12°34'.8	9.3	3.9'x3.9'
NGC 3384	Galaxy spiral	10h48m.3	+12°37'.7	9.9	5.5'x2.9'
NGC 3389	Galaxy spiral	10h48m.5	+12°31'.9	11.9	2.7'x1.1'
Wolf 359	Star	10h56m.3	+07°00'.8	13.4	-
NGC 3521	Galaxy	11h18m.9	+13°05'.5	9.3	8.7'x2.2'
NGC 3623 M65	Galaxy	11h05m.8	-00°02'.2	9	12.3'x6.5'
ULAS J 1120+0641	Quasar	11h20m.1	+06°41'.4	-	-

NGC 3627 M66	Galaxy	11h20m.2	+12°59'.5	8.9	8.2'x3.9'
NGC 3628	Galaxy	11h20m.3	+13°35'.3	9.5	14'x4'
NGC 3758	Galaxy	11h36m.4	+21°36'.2	9.3	8.7'x2.2'


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