ASTROPHYSICS RESEARCH
University of the Free State

UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA

UFS·UV
NATURAL AND
AGRICULTURAL SCIENCES
NATUUR- EN
LANDBOUWETENSKAPPE

Group Members: 2013

Ph.D

A. Odendaal

H van Heerden

Prof. P.J. Meintjes

M.Sc

D Wium

J Maritz

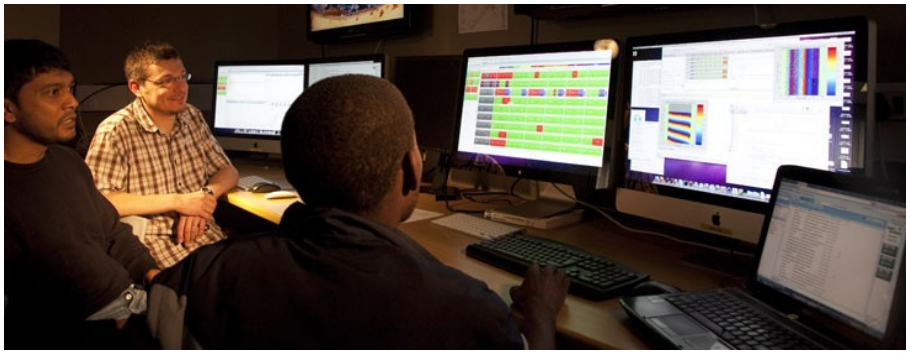
Hons

J. Coetzee

Dr. B van Soelen

SKA AFRICA
SQUARE KILOMETRE ARRAY

SKA Funding



Undergraduate Program

Learning programme 3: Astrophysics (4344)

In this learning programme Astrophysics is presented together with Physics. During undergraduate studies, the modules in Astrophysics are resource based modules presented by the University of South Africa (UNISA) and count 12 credits each (irrespective of the last number in the code). Students who have successfully completed their studies can pursue postgraduate studies in basic Physics with Astrophysics modules which can lead to a MSc and PhD degree in Physics specialising in Astrophysics. Career possibilities include that of astronomer (astrophysicist) as well as physicist (see learning programme 1).

Year		Semester 1	Semester 2
1	**Compulsory**		
	- Astronomy	FSK154	FSK164
	- Physics	FSK114	FSK124
	- Mathematics	WTW114	WTW124
	- Computer Literacy	BRS111	BRS121
	One module per semester from:		
	- Chemistry	CEM114	CEM124
	- Computer Information Systems	RIS114 or RIS134	RIS124 or RIS144
	- Geology	GLG114	GLG124
	- Mathematical Statistics	WKS114	WKS124 or STK124
2	**Compulsory**		
	- Astronomy (year modules)	AST251, AST252, AST255	
	- Physics	FSK214+FSK232	FSK224+FSK242
	- Mathematics and Applied Mathematics		WTW244
	Enough modules to obtain 36 credits from:		
	- Mathematics and Applied Mathematics	WTW214, WTW234, WTW254	WTW224, WTW264
	- Chemistry	CEM232, CEM214	CEM242, CEM224
	- Computer Information Systems	RIS214	RIS224, RIS264
	- Geology	GLG212, GLG214	GLG222, GLG224
	- Mathematical Statistics	WKS216	WKS226
3	**Compulsory**		
	- Astronomy (year modules)	AST354, AST355	
	- Physics	FSK314+FSK332+ FSK352+FSK372	FSK324+FSK342+ FSK362+FSK382
	- Mathematics and Applied Mathematics		WTW384
	Optional:		
	- Community service learning	NEC302 (year module)	

* Students choosing this learning programme must apply to UNISA during their first year and register during their second year to take the AST-modules. The module codes at UNISA differ slightly from those at the UFS as follows:

UFS	AST251	AST255	AST252	AST354	AST355
UNISA	AST2651	AST2655	AST2652	AST3763	AST3755

FSK154 (16 credits) – Introductory astronomy
(Department of Physics)

Three one-hour lectures per week during the first semester.
One examination paper of two hours.

The sky as a celestial sphere, including the visibility of stars and constellations; Cycles of the moon, the seasons and eclipses; Heliocentric universe and Kepler's laws of planetary motion; Stars, their types, structure, spectral classification and the Hertzsprung-Russell diagram; formation, evolution and death of stars; neutron stars and black holes; Galaxies and the Milky way; The big bang and the age of the universe; Astronomical measurements and techniques applicable to multi-wavelength astronomy.

After successful completion of the module the student will be able to:

a) define basic astronomical terms and explain phenomena associated with the motion of the earth and moon.
b) describe and interpret the laws governing motion of the planets.
c) describe the birth, evolution and death of stars.
d) describe the structure and basic properties of galaxies, and the theory of the big bang.
e) interpret data obtained from different wavelength observations (multi-wavelength astronomy).

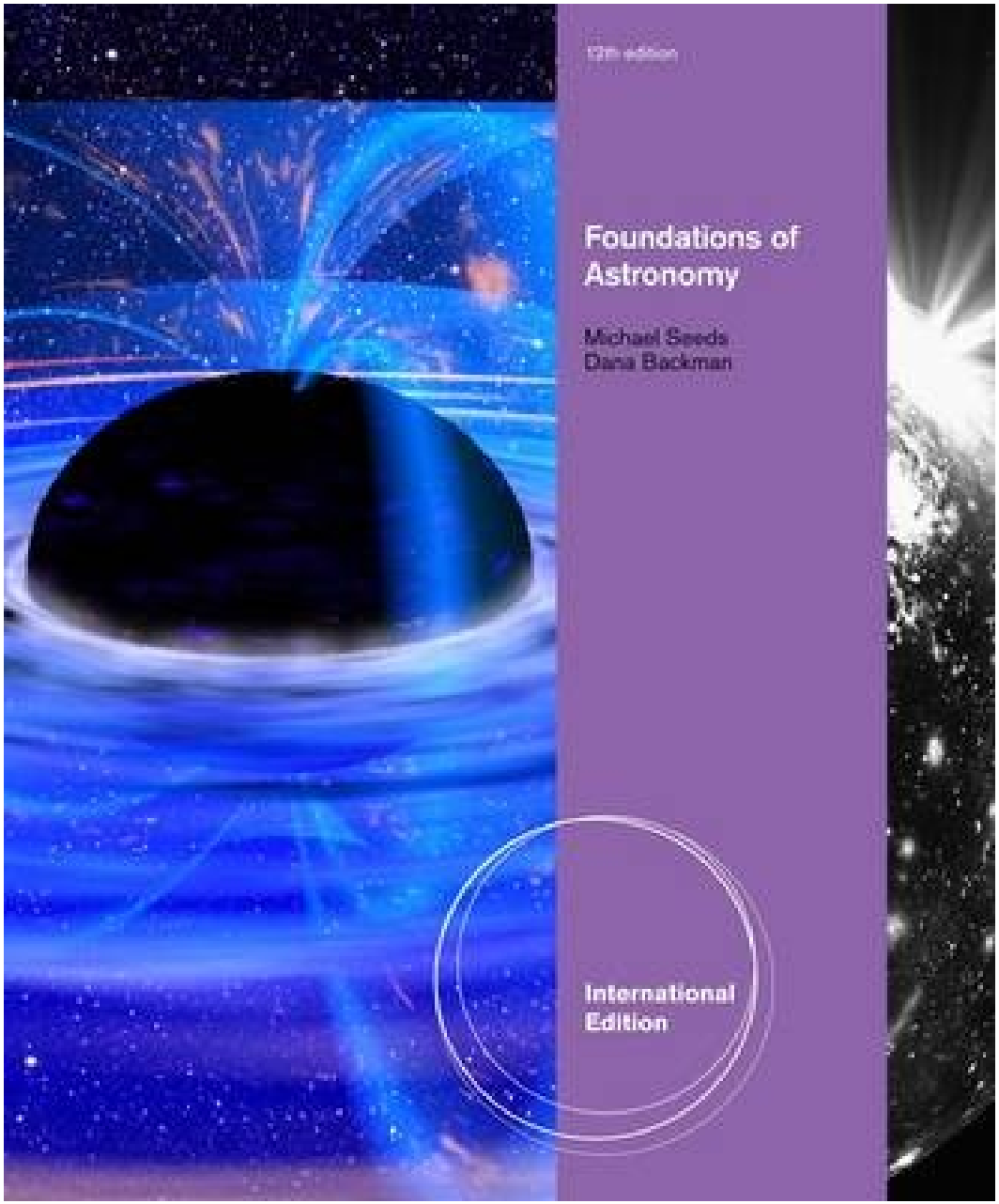
FSK164 (16 credits) – Principles and Practice of Observational Astronomy
(Department of Physics)

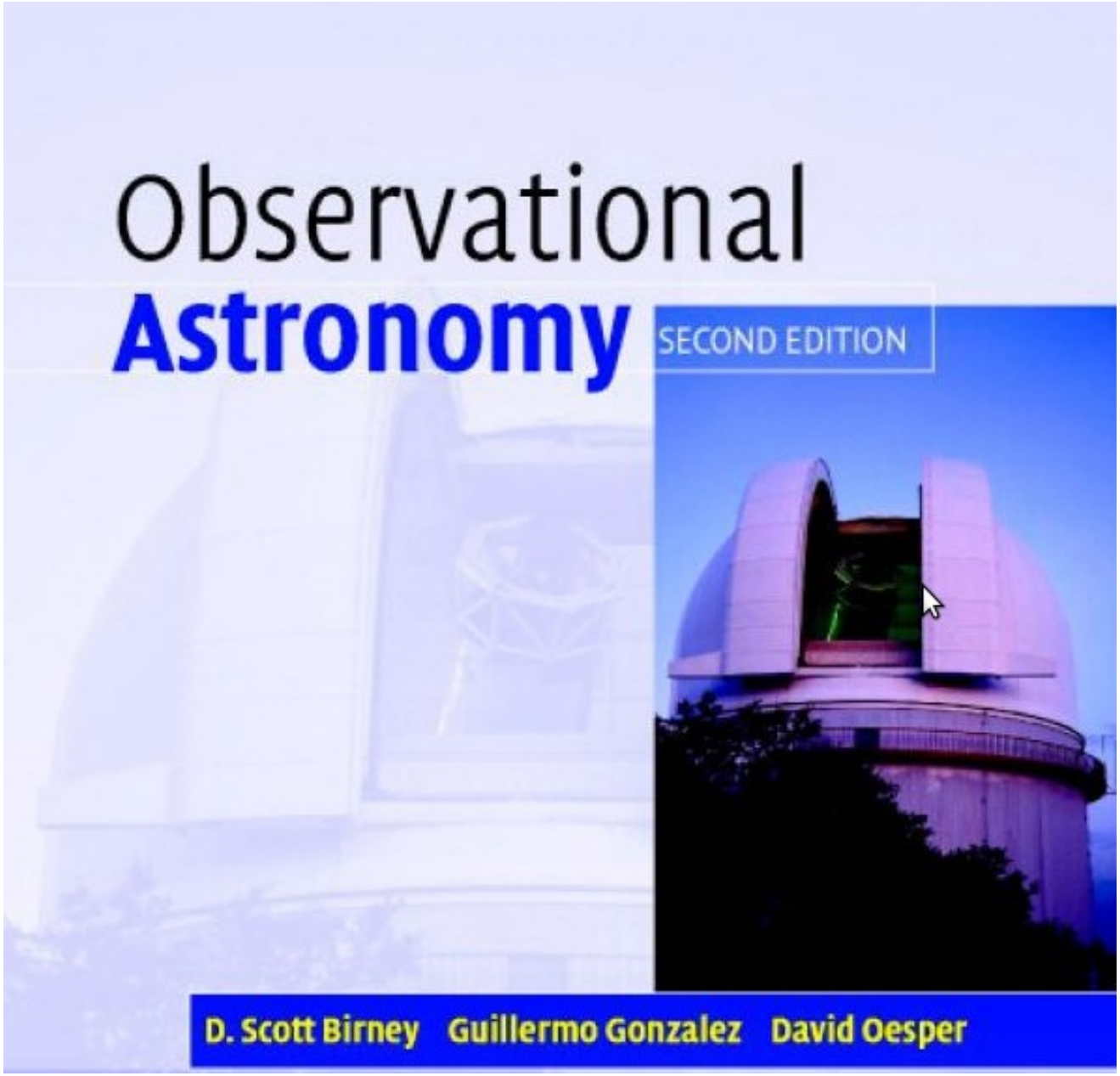
Three one hour lectures per week during the second semester.
Six practical sessions during the second semester
One two hour exam paper.

a) Astronomical Instrumentation: Telescopes (Radio, Infrared, Optical, X-ray and Gamma-Ray)
b) Telescope Optics (Resolving Power and Magnification).
c) Astronomical Observations and Measurements: Photometry, Spectroscopy, Parallax measurements to determine distances to stars.
d) Introduction to the Celestial Sphere, Basics of spherical geometry.
e) Coordinate systems: Equatorial (RA-Dec), Alt-Az system, Ecliptic coordinates, Galactic Coordinates, Sidereal Time.
f) Introduction to Celestial Mechanics (Two Body problem).
g) Introduction to practical CCD photometry.

After successful completion of the module the student should:

- Apply the basic principles of observational astronomy in problems and practice with astronomical instrumentation, i.e. discuss and differentiate between different astronomical instrumentation, apply theoretical concepts of spherical trigonometry to practical problems in positional astronomy.
- Apply basic theoretical concepts in practical applications.


12th edition
Foundations of Astronomy
Michael Seeds
Dana Backman
International Edition


Observational
Astronomy
SECOND EDITION
D. Scott Birney
Guillermo Gonzalez
David Oesper

FSIK372 (8 credits) – Radiative processes I
(Department Physics)
One lecture per week during the first semester.
One examination paper of two hours.
Fundamentals of radiative transport, intensity, radiative momentum and transfer, thermal radiation, the Einstein coefficients, scattering effects random walks and radiative diffusion. A brief introduction of radiation fields, review of Maxwell's equations. Plane electromagnetic waves, Electromagnetic potentials. The radiation of moving charges: the Larmor formula, Thomson scattering, radiation from harmonically bound charges. Introduction of relativistic mechanics, emission of relativistic particles, invariant phase volumes and specific intensity. An investigation of the fundamentals of radiation propagating through a magnetized plasma, e.g. introducing the plasma frequency, Faraday rotation and Cerenkov radiation, the Razin effect.
After successful completion of the module the successful student should:

a) have a solid and useable background in the fundamentals of radiation transport and radiation of individual charged particles, and be familiar with the concepts of radiative flux, specific intensity, radiative transfer, thermal radiation, the Einstein coefficients, scattering effects (random walk) and radiative diffusion, the basic radiation fields, Maxwell's equations, plane electromagnetic waves, retarded potentials for single charges, velocity and radiation fields, radiation of non-relativistic systems of particles, Thomson scattering, as well as radiation reaction and the radiation of harmonically bound particles as a mechanical model for the emission of bounded particles, four-vectors, and the relativistic expressions for the fields of charged particles and some basic properties of relativistic mechanics;
b) have the necessary background to solve basic problems in this discipline, and apply basic concepts to solve problems related to radiation transport in astrophysical environments like stellar atmospheres and molecular clouds and supernova remnants, the propagation of electromagnetic waves in a non-conducting and conducting medium, the power radiated by rotating magnetic objects (pulsars) and accelerated single charged particles and oscillating dipoles, relativistic mechanics.

FSIK382 (8 credits) – Radiative processes II
(Department Physics)
One lecture per week during the second semester.
One examination paper of two hours.

The emission of single speed electrons in the vicinity of a massive nucleus, thermal bremsstrahlung emission, relativistic bremsstrahlung, synchrotron emission, expressions for the total emitted power, beaming, Compton and inverse-Compton scattering, cross section, energy transfer and spectral regimes, atomic structure (review of the Schrodinger equation and fundamentals of atomic physics), Zeeman effect and hyperfine structure, thermal distribution of ionized energy levels leading to the Saha equation, radiative transitions (Milne relations)and line broadening mechanisms, e.g. Doppler broadening, natural broadening and collisional broadening mechanisms.
After successful completion of the module the successful student should:

a) have a useable background in the fundamental aspects of radiation processes of single charged particles, and be familiar with bremsstrahlung, the basic properties of synchrotron radiation, Compton and inverse-Compton scattering, atomic processes related to radiation, e.g. Zeeman splitting, hyperfine structure, the Saha equation and radiative transitions and line broadening mechanisms;
b) have the necessary background to solve basic problems in this discipline, and apply fundamental concepts introduced above to solve basic problems related to: bremsstrahlung, synchrotron radiation of single particles, Compton and inverse-Compton radiation, atomic processes related to radiation and radiation transport.

Graduate program

(x) Physics – Study Code 4518

A student must have achieved an average mark of at least 60% in (FSK314 + FSK332 + FSK352 + FSK324 + FSK342 + FSK362) to qualify for admission to the Honours degree. The Departmental Chairperson may grant permission for admission to the Honours degree in exceptional cases. The programme commences in middle January and students must apply for admission with the Departmental Chairperson before that date.

The curriculum is composed in consultation with the Departmental Chairperson from the modules listed below. The complete curriculum must consist of at least eight modules, plus the practical module FSK692 which is compulsory. Each module must be independently passed.

The degree can be offered over more than one year. Postgraduate modules from other subject disciplines can also be offered in consultation with the Departmental Chairperson.

Modules			**Credits**
FSK601	-	Quantum Mechanics*	16
FSK602	-	Solid State Physics I*	16
FSK603	-	Research Techniques*	16
FSK604	-	Mathematical Methods of Physics	16
FSK605	-	Solid State Physics II*	16
FSK606	-	Semi-conductors*	16
FSK607	-	Statistical Physics	16
FSK608	-	Electrodynamics	16
FSK609	-	Materials Science I*	16
FSK610	-	Materials Science II*	16
FSK611	-	Electronics*	16
FSK612	-	Astrophysics	16
FSK613	-	*Capita Selecta I*	16
FSK614	-	*Capita Selecta II*	16
FSK692	-	Research essay*	32

Not all these topics are necessarily offered in a given year.

* Students wanting to do an MSc in Surface Physics are strongly recommended to register for these courses.

NB. Successful completion of all the necessary Honours modules of the National Astrophysics and Space Science Programme (NASSP) (www.star.ac.za) will be recognised by crediting the student with FSK625 (120 credits), the only requirement for BScHons (National Astrophysics and Space Science Programme). These students should register under study code 4580.

C

NASSP

NASSP Consortium

University of Cape Town
University of KwaZulu-Natal, Durban Campus
University of KwaZulu-Natal, Pietermaritzburg Campus
University of the Free State
North-West University, Potchefstroon
University of Zululand
Rhodes University
University of the North West, Mabatu Campus
University of South Africa
University of the Western Cape
University of the Witwatersrand
South African Astronomical Observatory
Hartebeesthoek Radio Astronomy Observatory
Hermanus Magnetic Observatory

NASSP Steering Committee

Catherine Cress	Thebe Medupe
Peter Dunsby	**Pieter Meintjes**
Mike Gaylard	Adri Burger
Justin Jonas	David Walker
Peter Martinez	Patricia Whitelock
Derck Smits	Pierre Cilliers
Fabio Frescura	

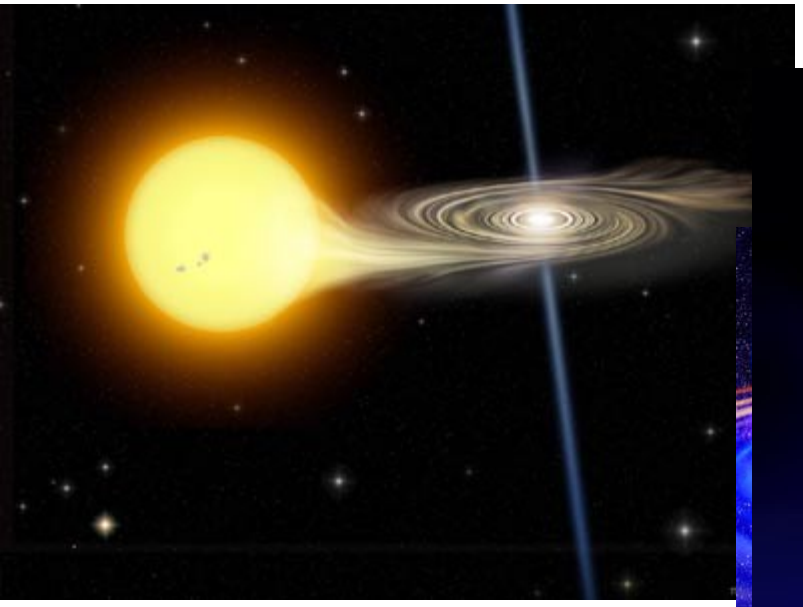
UFS NASSP Students

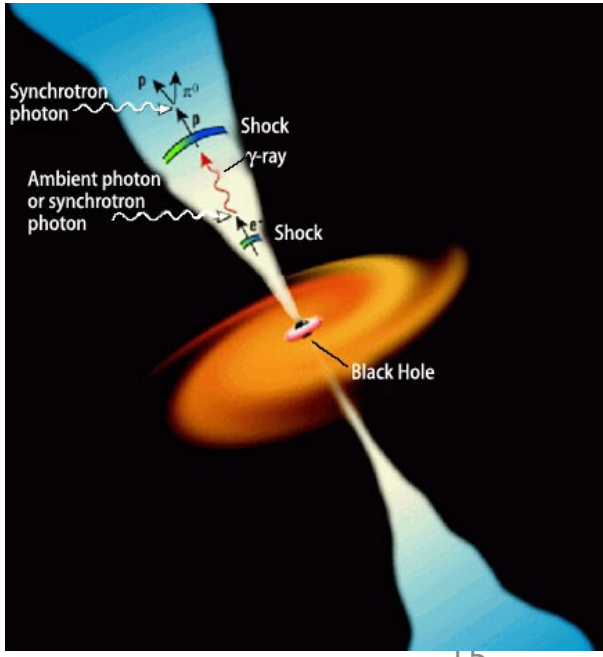
- Uganda (2 M.Sc, 2 PhD)
- Rwanda (1 M.Sc, 1 PhD)
- UCT (1 M.Sc, PhD in Southampton)
- Stellenbosch (1 M.Sc)

NASSP Students at Boyden

NASSP Students graduating at UFS

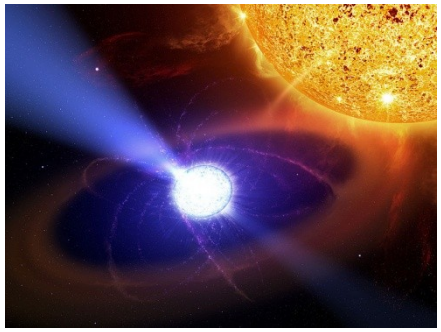
Galactic to Extra-Galactic



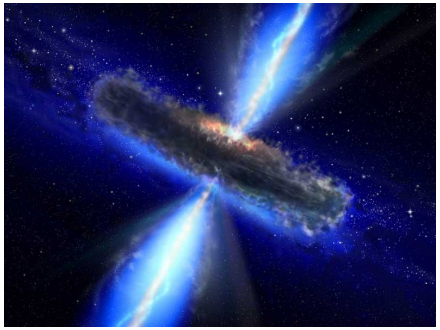


Research

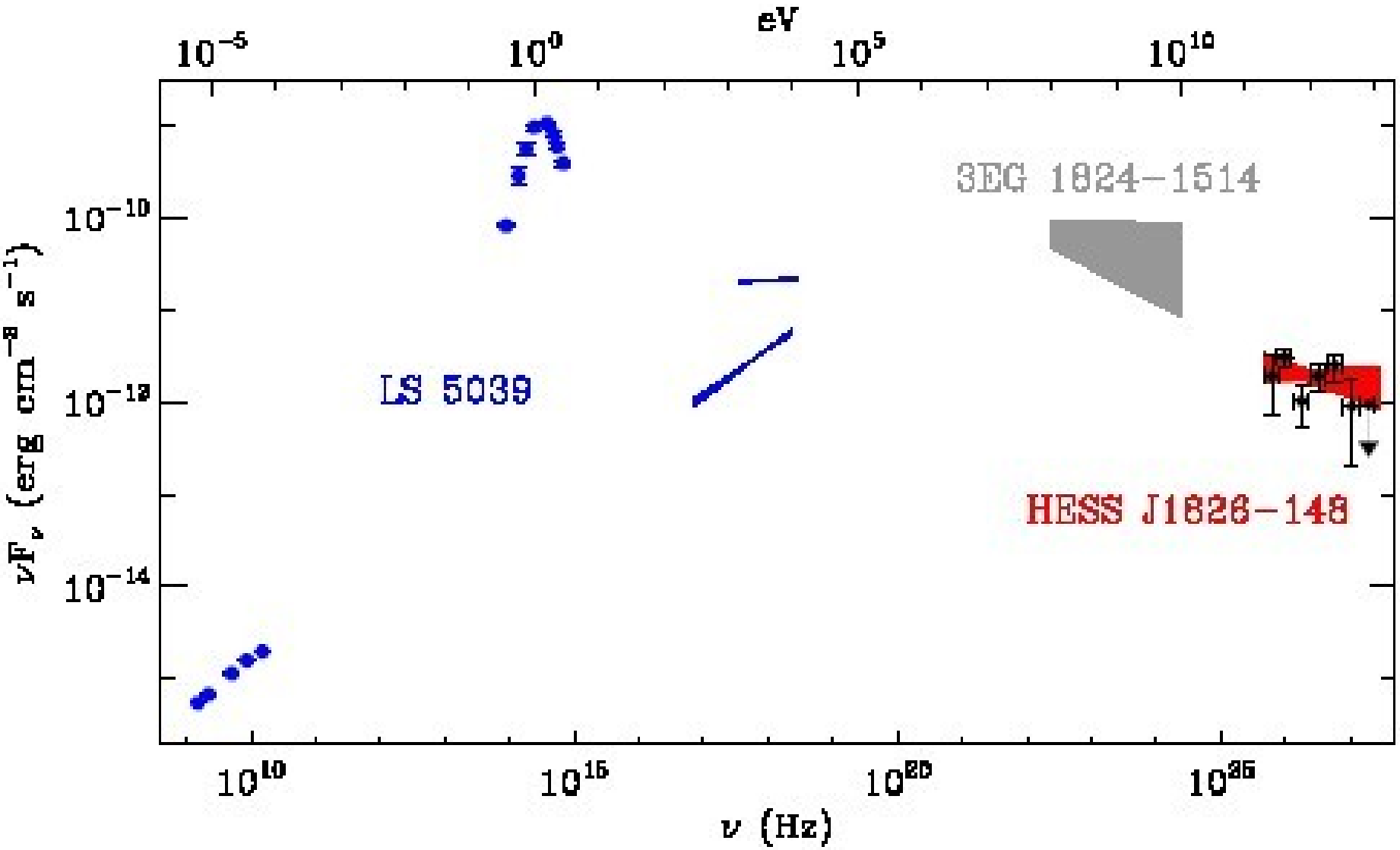
Multi-wavelength astrophysics of galactic and extragalactic accretion driven systems:



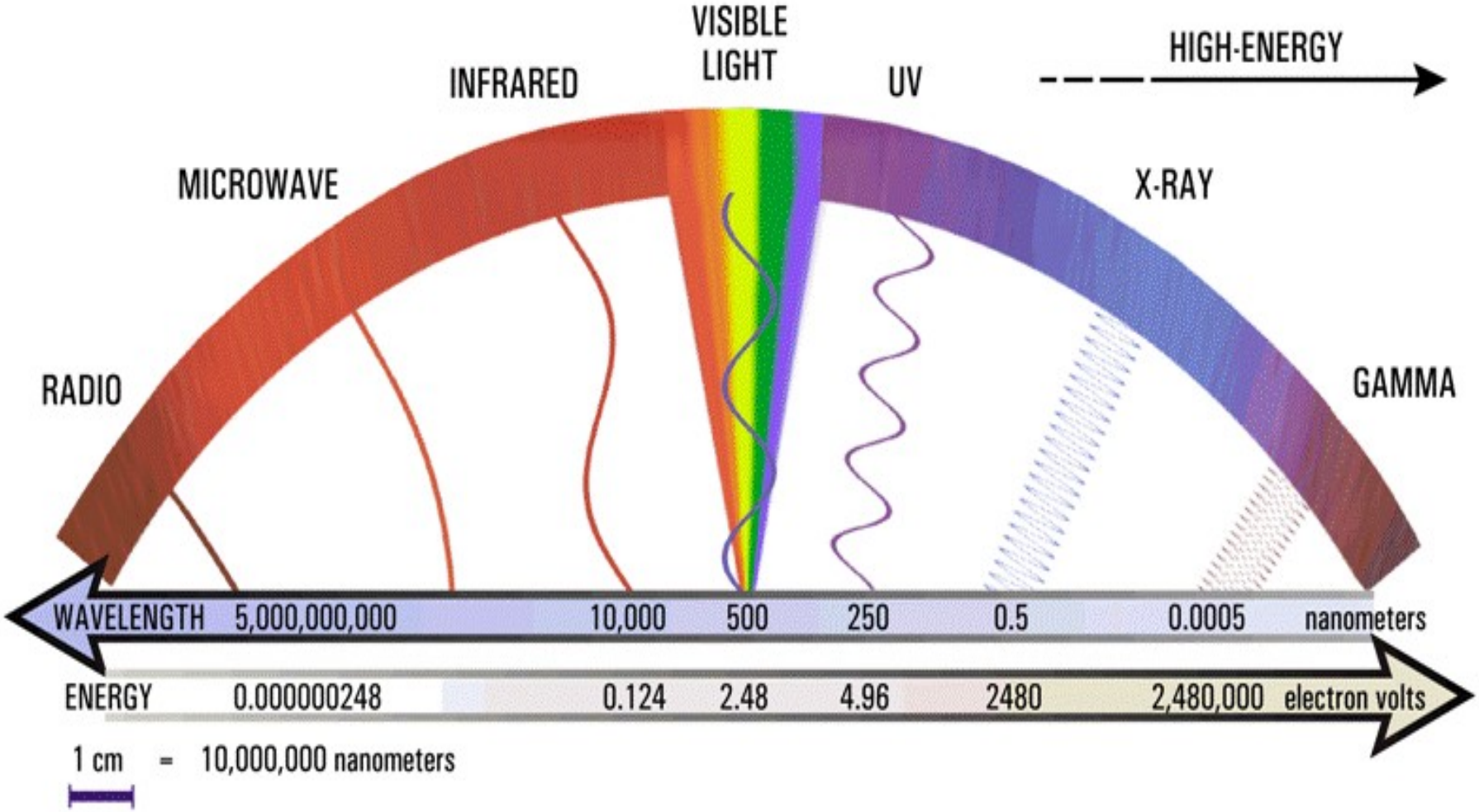
- **Cataclysmic variables**
- **Super Soft X-ray sources**
- **Gamma-Ray Binaries**
- **Search for blazars and other active galaxies among unidentified sources detected by EGRET and Fermi gamma-ray satellites**
- **Gravity wave signatures in astrophysical processes**



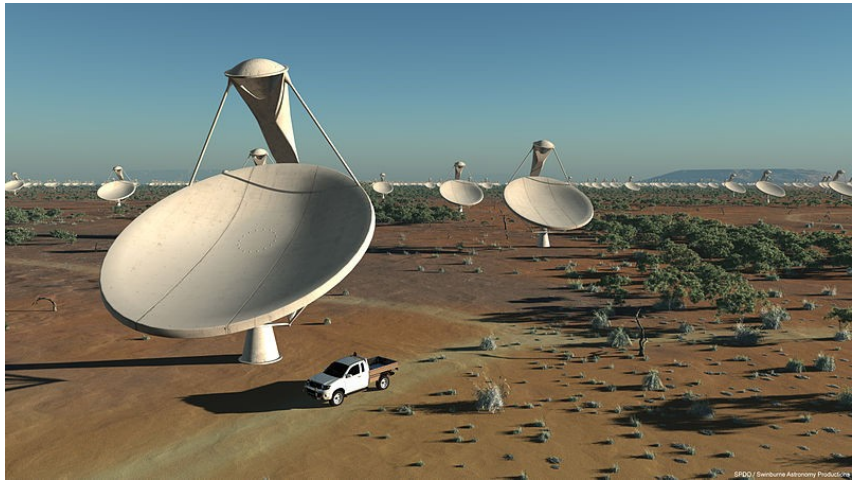
Multi-Wavelength



Multi-Wavelength Astrophysics



UFS: Active centre for multi-wavelength astrophysics in SA



Utilizing Existing Infrastructure in South Africa

SALT

Sutherland

HartRao

Other International Facilities

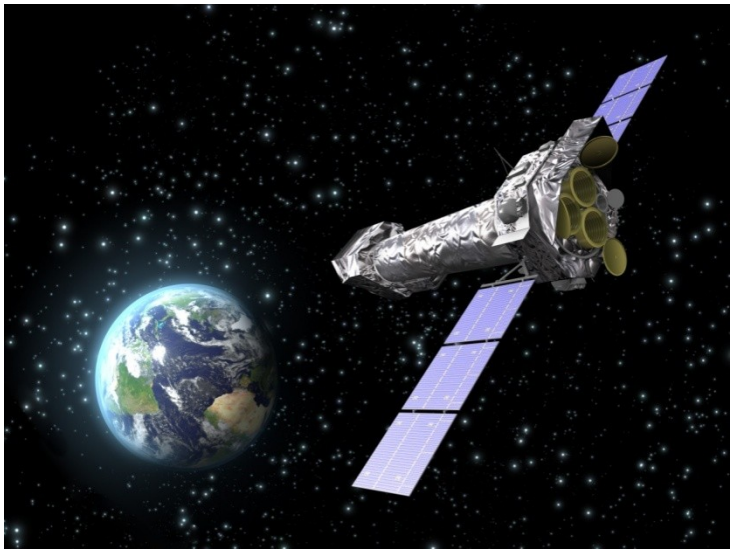
CTIO - 4.1 m SOAR Telescope

Other International Facilities

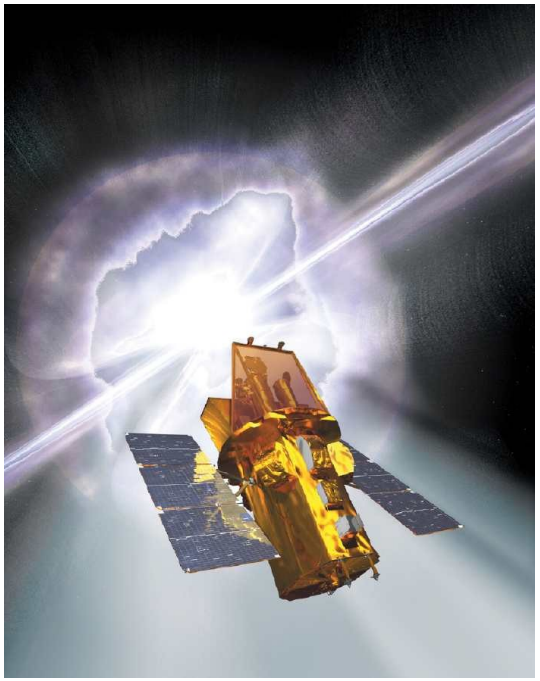
VLT – Cerro Paranal

X-ray

Chandra



XMM-Newton

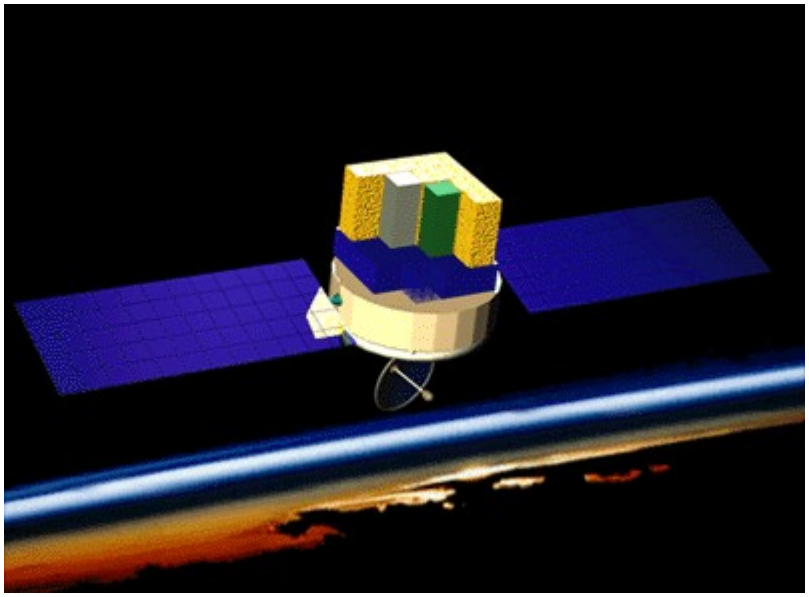


Swift

Gamma-Ray

CGRO-EGRET (100MeV-20 GeV)

Fermi-LAT (100MeV-300 GeV)

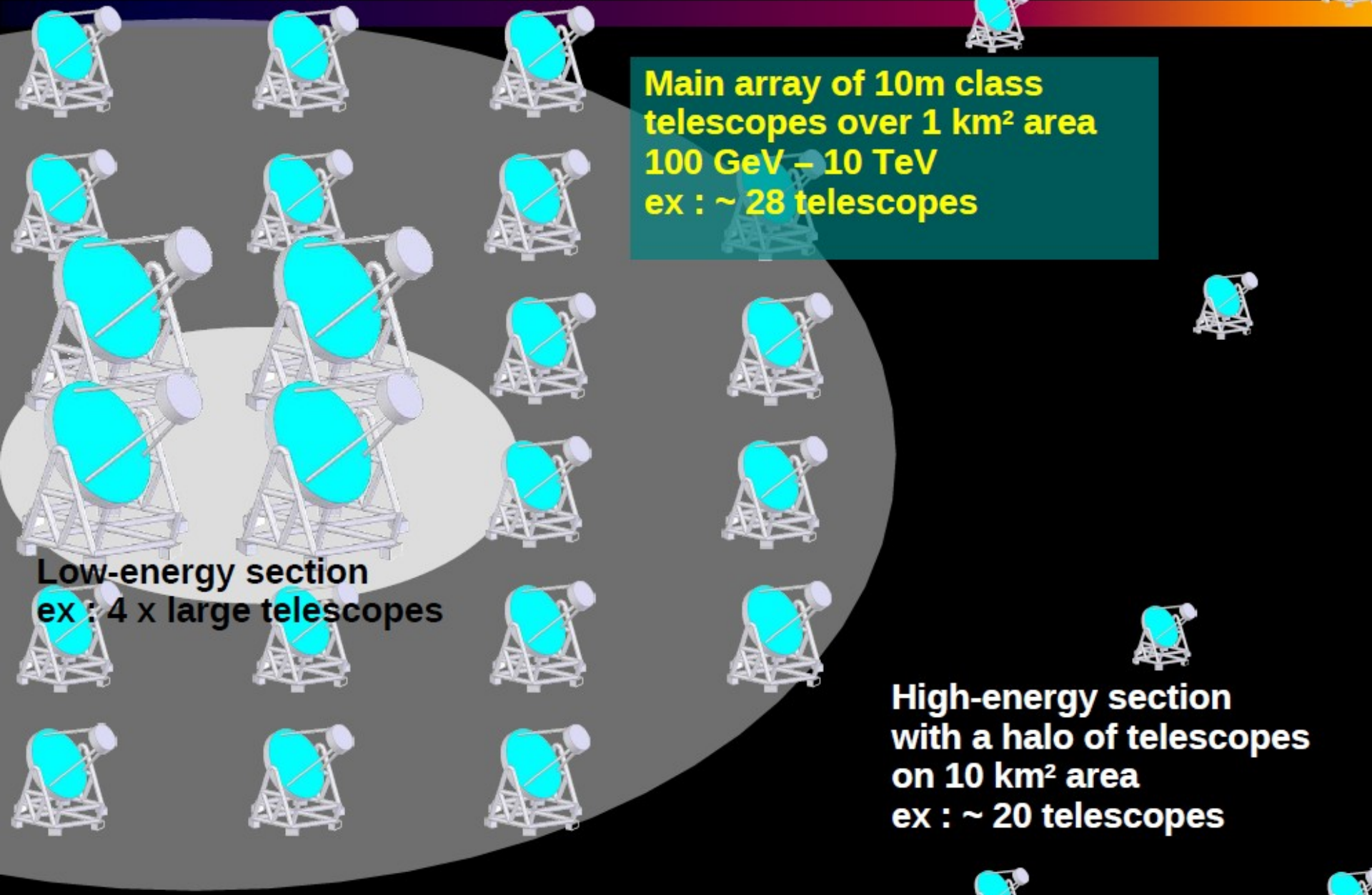


UFS-High Performance Computing Facility

- Coded in Fortran, 64bit Intel compiler
- To speed things up this is run on one of the 8 CPU node at the HPC at UFS
  - 26 x Dell 1950 Nodes with the following configuration:
    - 2 x Intel Xeon Quad Core CPUS (8 Cores Per node)
    - 8 - 16GB Memory
  - Upgrade
    - 17 x Super Micro nodes with the following configuration:
    - 4 x AMD Opteron 6174 12-Core CPUS (48 Cores per node)
- Thanks to Albert van Eck

From 2013 – HESS II

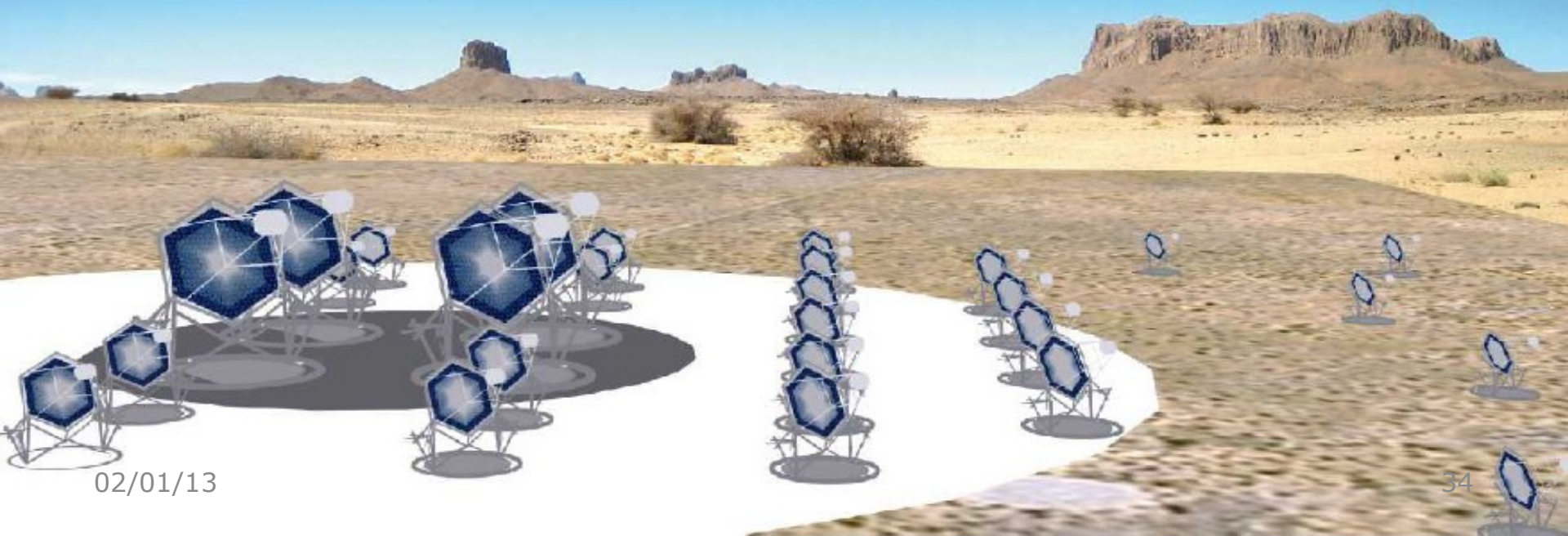
CTA Concept: 50-100 mixed telescopes



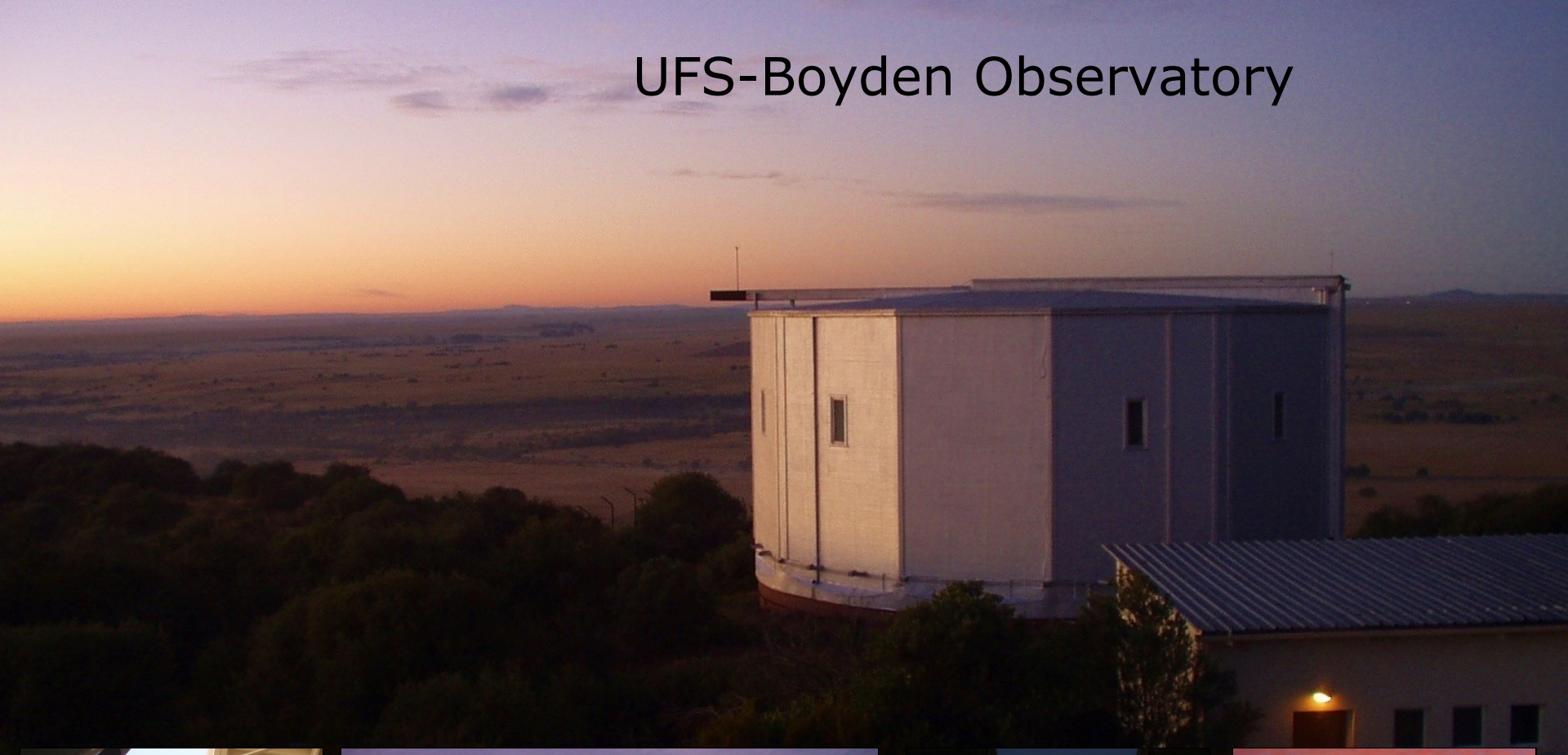
UFS-NWU-WITS consortium

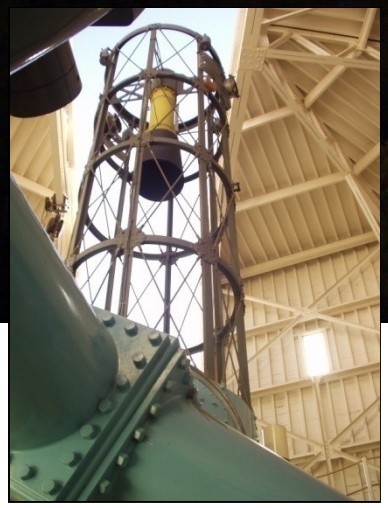
Cerenkov Telescope Array (CTA)

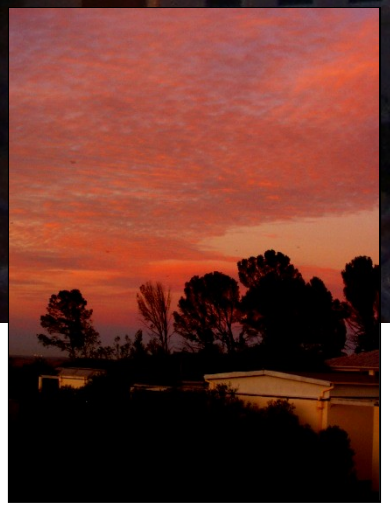
- **Astrophysics research**
- **Material Science- experimentation with new reflecting coatings**



UFS-Boyden Observatory







Getting the Public Interested


Patrick Seitzer

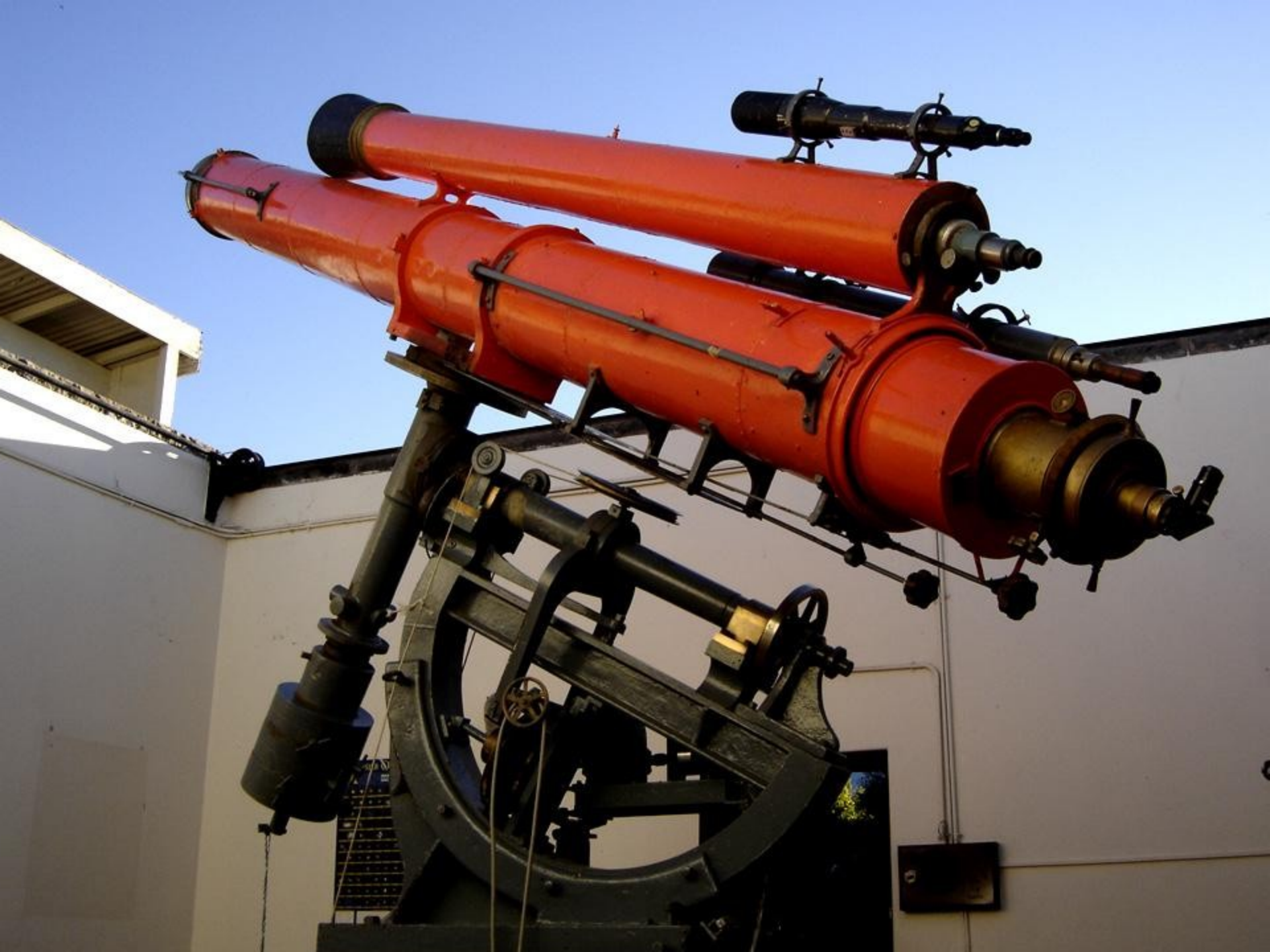

Phil Charles


Kevin
Govender

ASSA Symposium

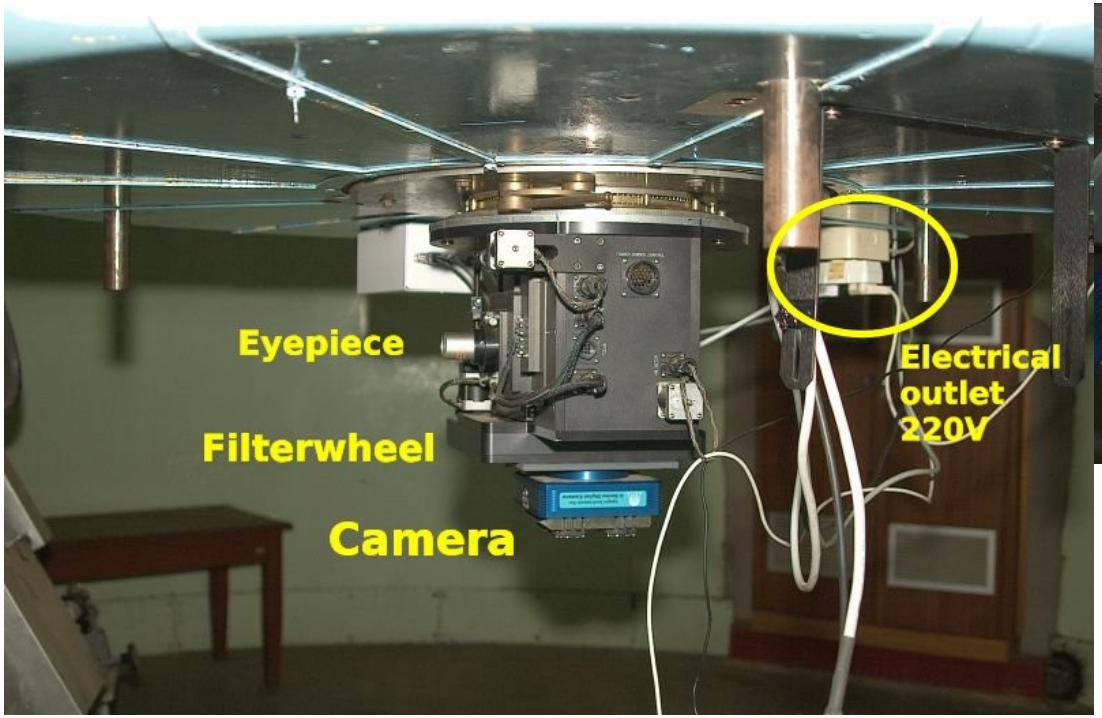
R26 million digital planetarium-UFS-Free State Covernment Collaboration

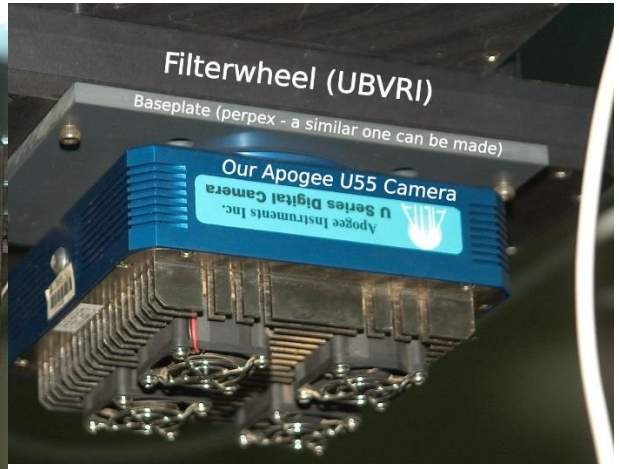
Metcalf- 10 inch-open evenings!!!




WATCHER 16 INCH

- Apogee CCD


Eyepiece
Filterwheel
Camera
Electrical
outlet
220V


Filterwheel (UBVRI)
Baseplate (perpex - a similar one can be made)
Our Apogee U55 Camera

14 inch Celestron-Student Training