

Optical Astronomy in South Africa

in support of multi-wavelength [transient] astrophysics



Optical Astronomy in South Africa

outline of this talk

I - National Strategy for Multi-Wavelength Astronomy in South Africa

- Human Capacity Development programs

II - Radio Astronomy in Africa

- MeerKAT and the Square Kilometre Array
- Radio transients : some examples

III - Optical Astronomy in South Africa in support of MWL astronomy

- SALT [see talk by Prof Petri Vaisanen earlier this week]
- MeerLICHT - the rise of the robots

Concluding remarks

Optical Astronomy in South Africa

a brief introduction



Patrick Woudt

Head of Department: Astronomy (2015-2019)
University of Cape Town [South Africa]

Science interests:

- Accretion and outflow in compact stellar binaries

Principal investigator:

- MeerKAT Large Survey Project on radio transients
- MeerLICHT



President: South African Institute of Physics (2017-2019)

I - Recent developments in Astronomy in SA

National strategy for multi-wavelength astronomy

Strategic objectives:

To promote **South African Astronomy research** and development to be **globally competitive**

To support **human capital development** that is **representative of the national demographics** and that develops world-class scientific, engineering and technical skills

To support **the strengthening and expansion of appropriate Astronomy infrastructure** that is both **world-class** and scientifically productive

To establish a **governance framework** to coordinate and integrate astronomy activities

To ensure that the advantages of Astronomy, such as **Big Data and the transfer of skills**, are translated into **socio-economic benefits** for South Africa

To promote outreach activities in support of **public awareness and education**

For more information, see:

<http://www.nrf.ac.za/media-room/news/dst-releases-national-strategy-multi-wavelength-astronomy>

I - Recent developments in Astronomy in SA

Dedicated capacity development programs

National Astrophysics and Space Science Program

- BSc Hons and MSc [since 2003] - entry into PhD programs at individual universities
- Typical annual intake: 20 BSc Hons and 10-20 MSc
- Expanded in 2016 to include three nodes: UCT, UKZN, NWU

SKA South Africa HCD program

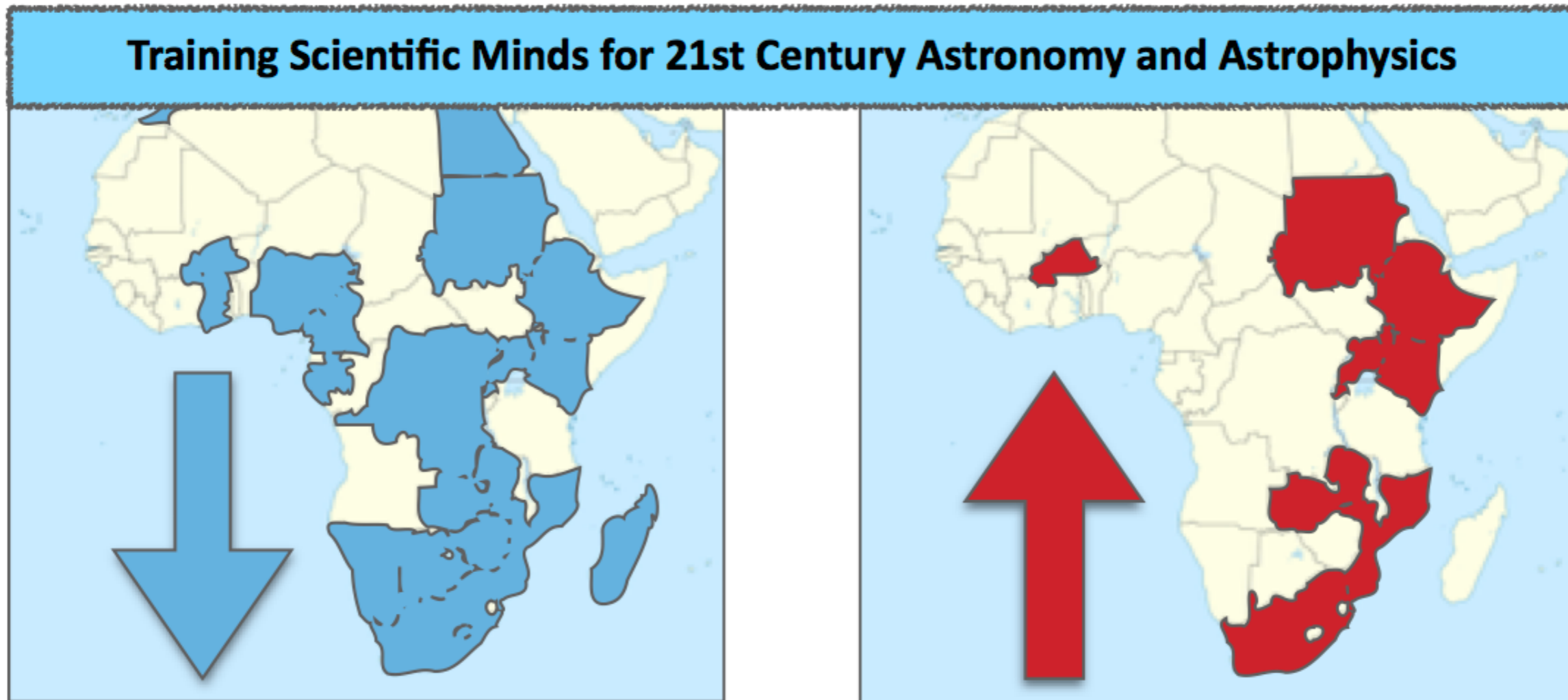
- Youth in Science and Engineering program [since 2006]
- >1000 scholarships across all levels (undergraduate/postgraduate/PhD)
- Across South Africa and SKA partner countries in Africa

Development in Africa with Radio Astronomy [DARA]

- Training program for students in African VLBI Network (AVN) partner countries
- In partnership with UK Newton fund
- Expanded to include DARA Big Data.

I - Recent developments in Astronomy in SA

Dedicated capacity development programs



Student mobility in NASSP [**based on 2003-2013 data** - should be updated in 2018]

Investment in physics in Africa through astrophysics

II - Radio astronomy in Africa

The mid-frequency component of the SKA

Conversion of unused telecommunication dishes in Africa - first African VLBI Network (AVN) dish in Kutunse (Ghana).
Opened July 2017.



MeerKAT, core of SKA1-Mid in South Africa.
To be opened in July 2018.



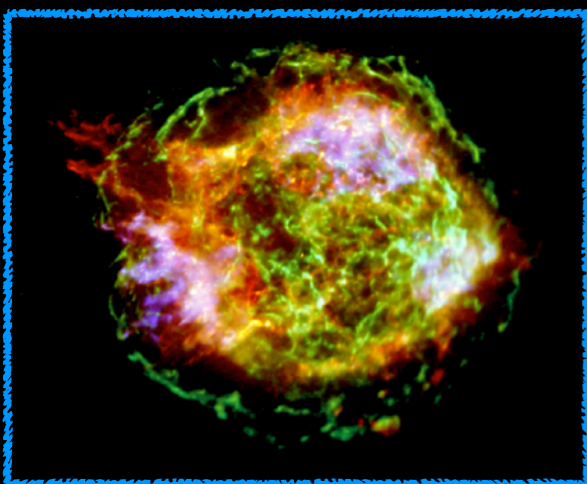
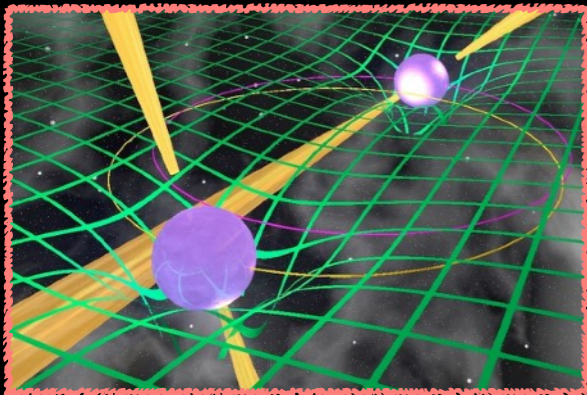
II - Radio Astronomy in Africa

MeerKAT as the precursor of SKA-1 MID



II - Radio Astronomy in Africa

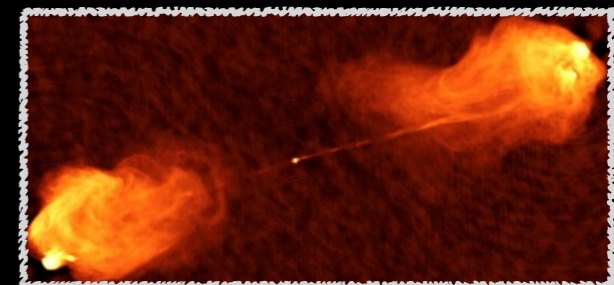
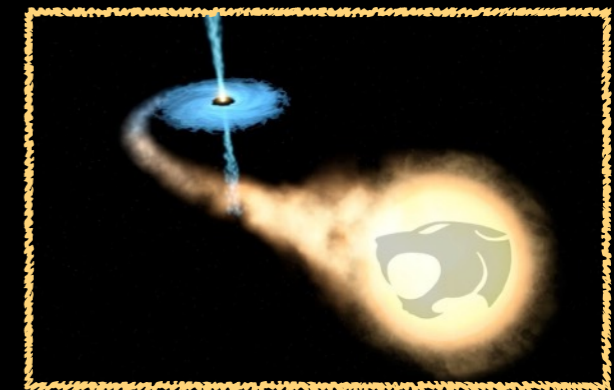
MeerKAT Large Survey projects [70% of time]



1. **MeerTime (binary)**
2. **MHONGOOSE**
3. **MeerTIME (MSPs)**
4. **LADUMA**
5. **Fornax**
6. **TRAPUM (Fermi sources)**
7. **MeerTIME (1000 PTA)**
8. **ThunderKAT (CVs)**
9. **MIGHTEE (L band)**
10. **ThunderKAT (GRBs)**
11. **MeerTime (GCs)**
12. **MALS (UHF and L band)**
13. **TRAPUM (nearby galaxies)**
14. **TRAPUM (GCs)**
15. **TRAPUM (SNR, PWN, TeV)**
16. **ThunderKAT (SNe Ia)**
17. **MIGHTEE (S band)**
18. **ThunderKAT (XRBs)**

ThunderKAT commensal image-plane search for transients (1 sec and up) in all LSP data

MeerTRAP commensal timing search (< 1 sec) in all LSP data



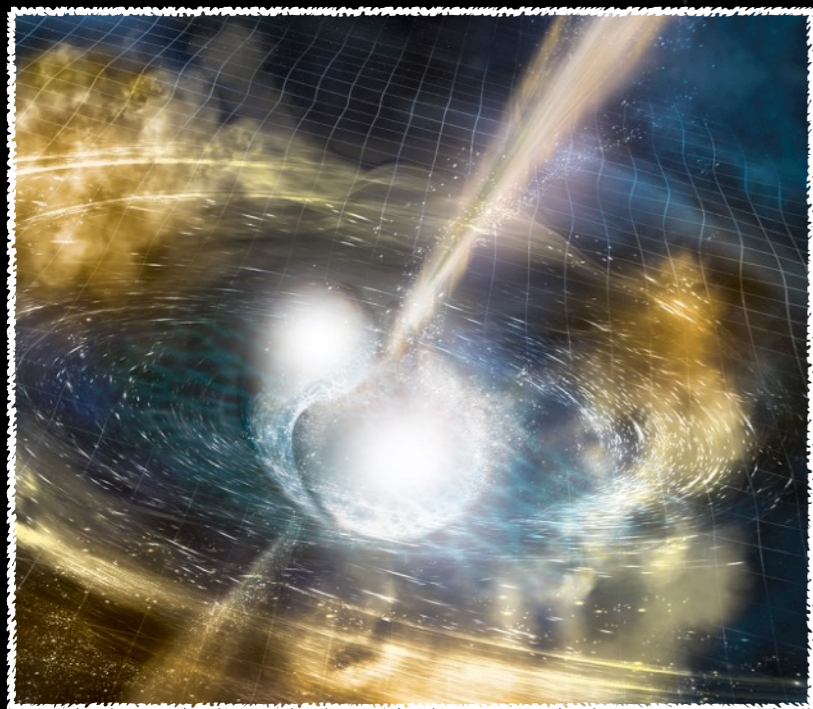
II - Radio Astronomy in Africa

Radio transients on MeerKAT

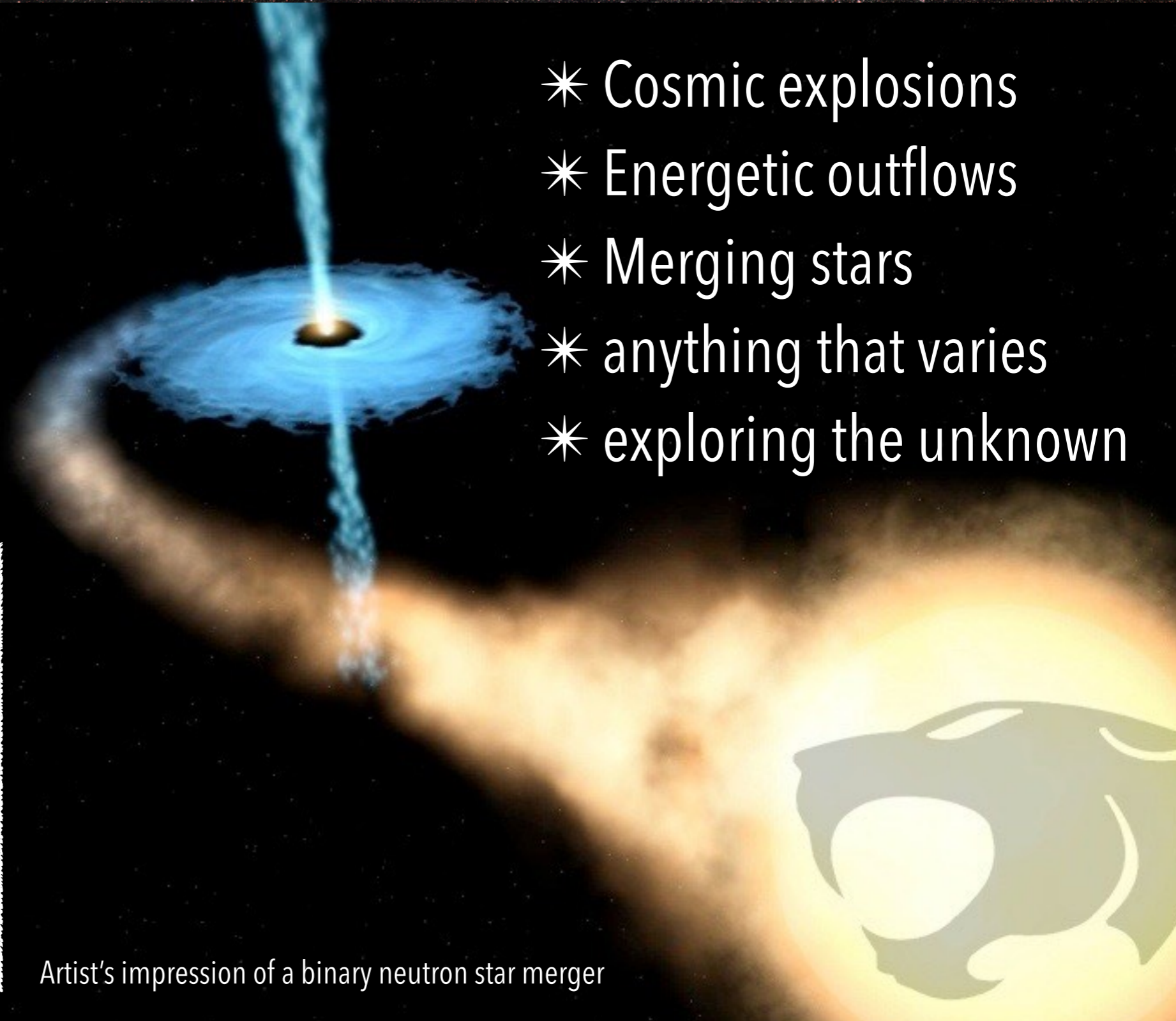
ThunderKAT commensal
image-plane search for
transients (1 sec and up)
in all LSP data

MeerTRAP commensal
timing search (< 1 sec) in
all LSP data

- * Cosmic explosions
- * Energetic outflows
- * Merging stars
- * anything that varies
- * exploring the unknown

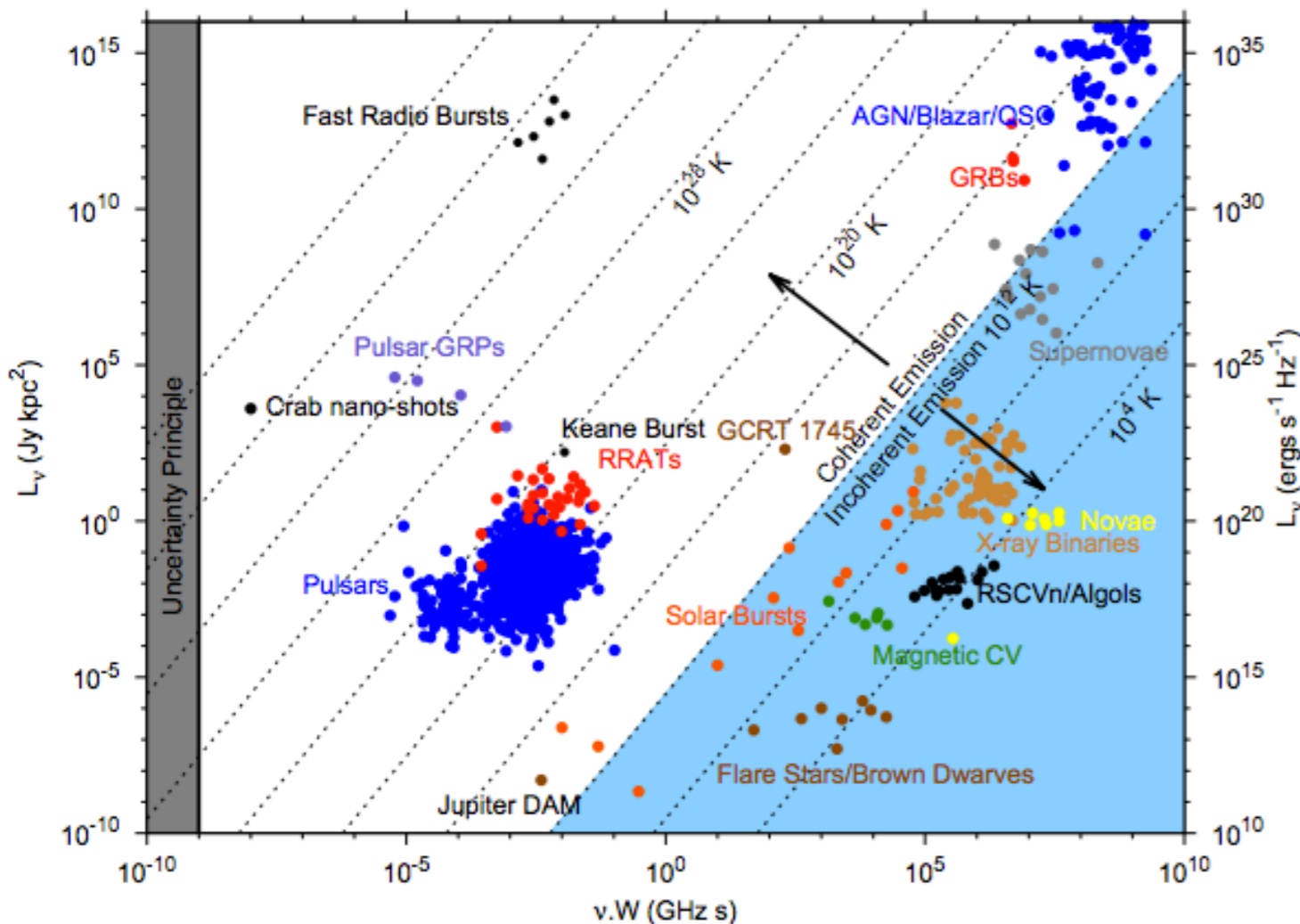


Artist's impression of a binary neutron star merger



II - Radio Astronomy in Africa

Radio transients



Coherent transients

Pulsars

Fast Radio Bursts

Time domain

TRAPUM @ MeerKAT

Incoherent transients

Synchrotron emission (shocks)

Accretion-induced (relativ.) outflow

Imaging domain

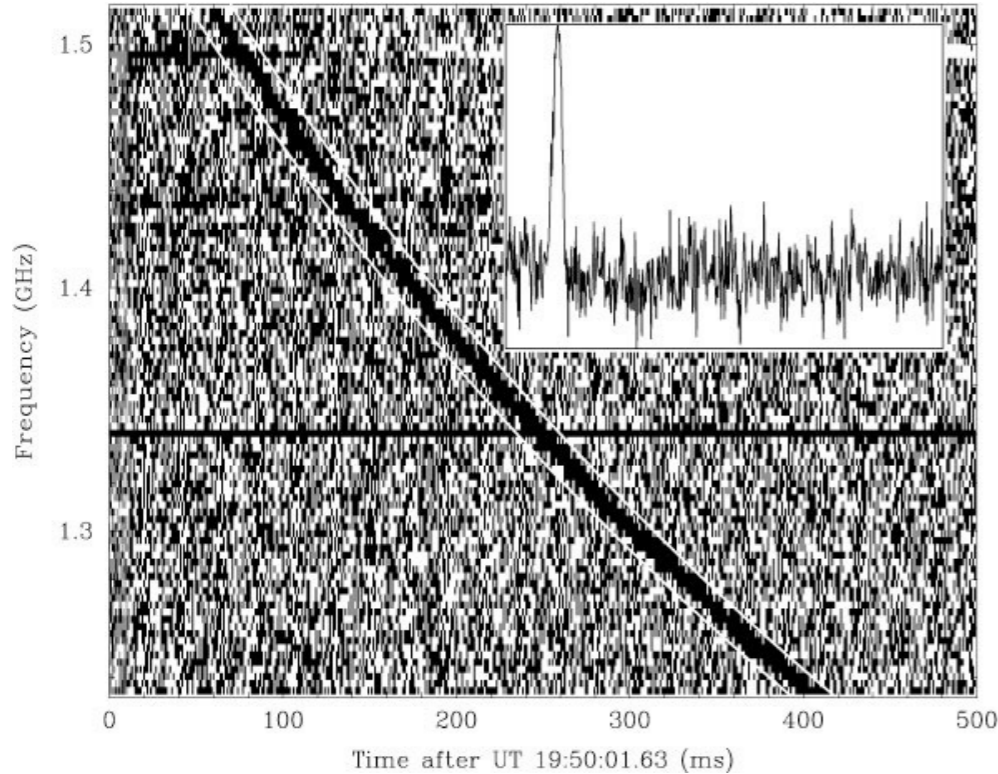
ThunderKAT @ MeerKAT

Boundary around ~1 second.

Coherent and Incoherent radio transients (Pietka, Fender, Keane 2015, MNRAS 446, 3687)

II - Radio Astronomy in Africa

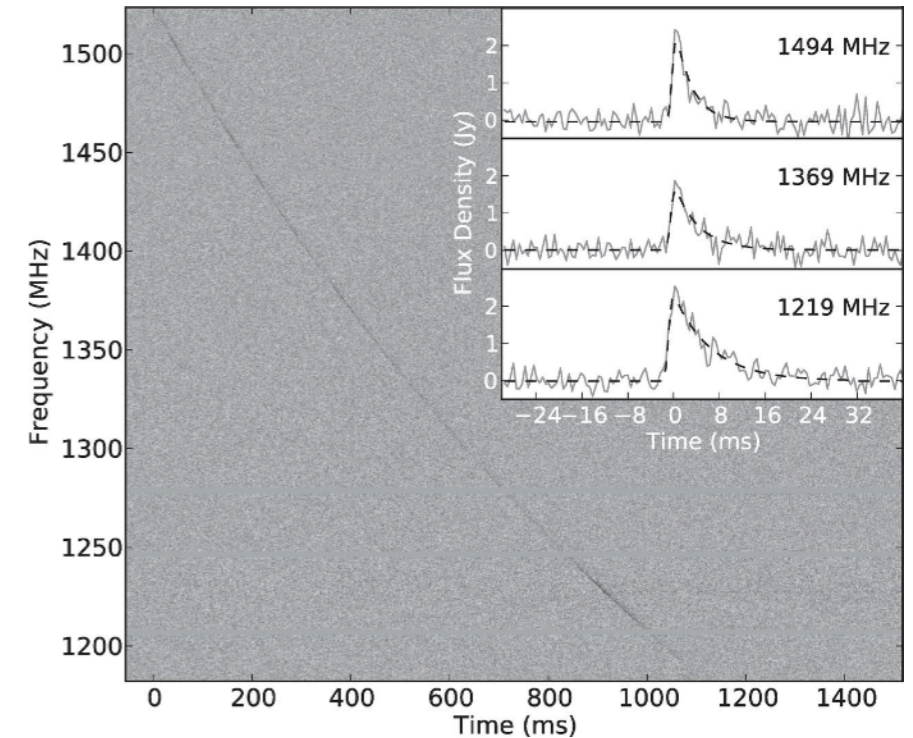
Fast radio bursts



The Lorimer burst

(Lorimer et al. 2007, *Science*, 318, 1459)

(Keane et al. 2012, *MNRAS*, 425, L71)



A Population of Fast Radio Bursts (FRB) at cosmological distances

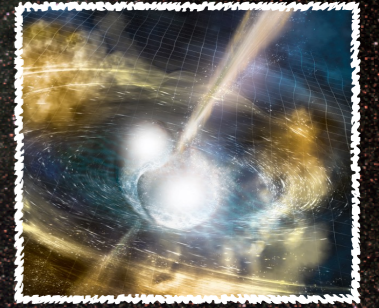
(Thornton et al. 2013, *Science*, 341, 53)

Distance? (only from dispersion measure) Nature of the FRB? **Optical counterpart?**

Cosmological probes: measuring baryon content (from DM contributions)

GW170817 - as observed from Africa

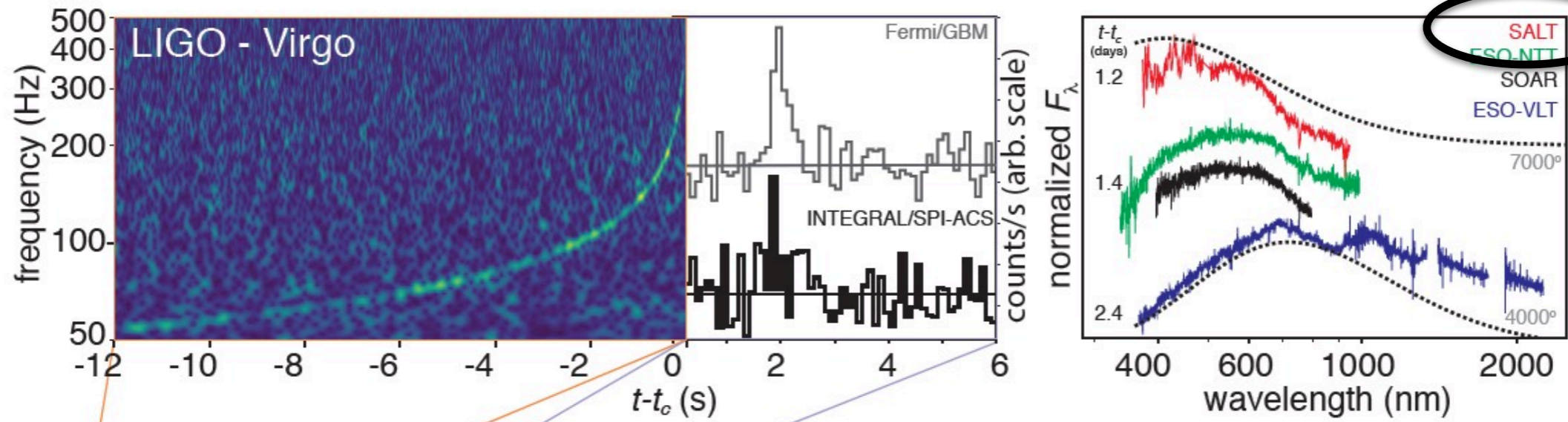
Multi-messenger astronomy



Earth

Space





GW
LIGO, Virgo

γ -ray
Fermi, INTEGRAL, Astrosat, IPN, Insight-HXMT, Swift, AGILE, CALET, H.E.S.S., HAWC, Konus-Wind

X-ray
Swift, MAXI/GSC, NuSTAR, Chandra, INTEGRAL

UV
Swift, HST

Optical

Swope, DECam, DLT40, REM-ROS2, HST, Las Cumbres, SkyMapper, VISTA, MASTER, Magellan, Subaru, Pan-STARRS1, HCT, TZAC, LSGT, T17, Gemini-South, NOT, GROND, SOAR, ESO-VLT, MMTNet, ESO-VST, VIRT, SALT, CHILESCOPE, TOROS, BOOTES-5, Zadko, iTelescope.Net, AAT, Pi of the Sky, AST3-2, ATLAS, Danish Teles, DFN, ROS, EABA

IR

REM-ROS2, VISTA, Gemini-South, 2MASS, Spitzer, NTT, GROND, SOAR, NOT, ESO-VLT, Kanata Telescope, HST

Radio

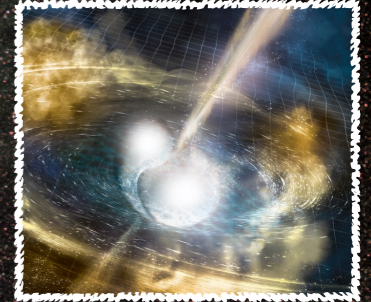
ATCA, VLA, ASKAP, VLBA, GMRT, MWA, LOFAR, LWA, ALMA, OVRO, EVN, e-MERLIN, MeerKAT, Parkes, SRT, Effelsberg

$t-t_c$ (s)

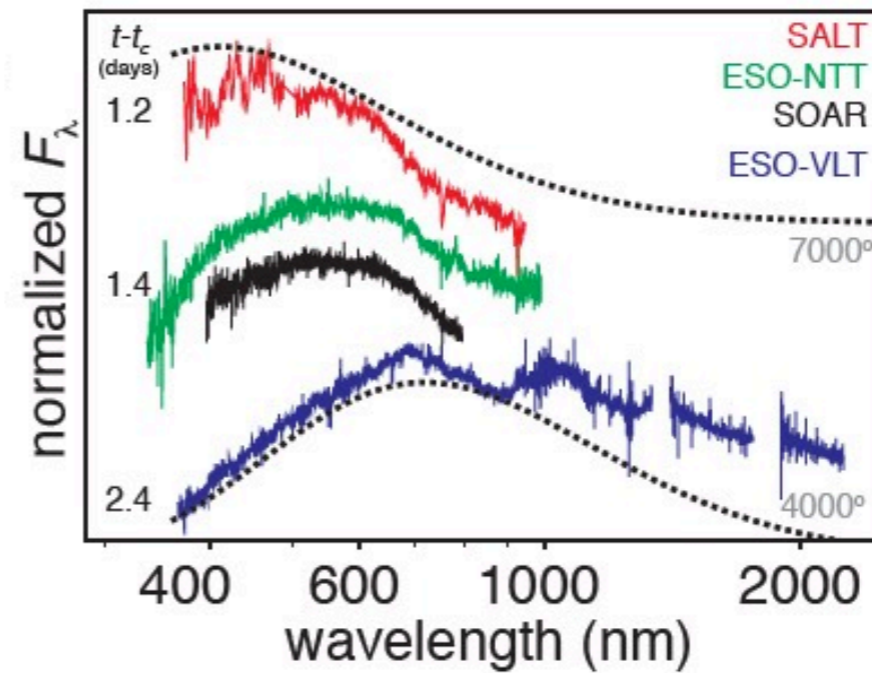
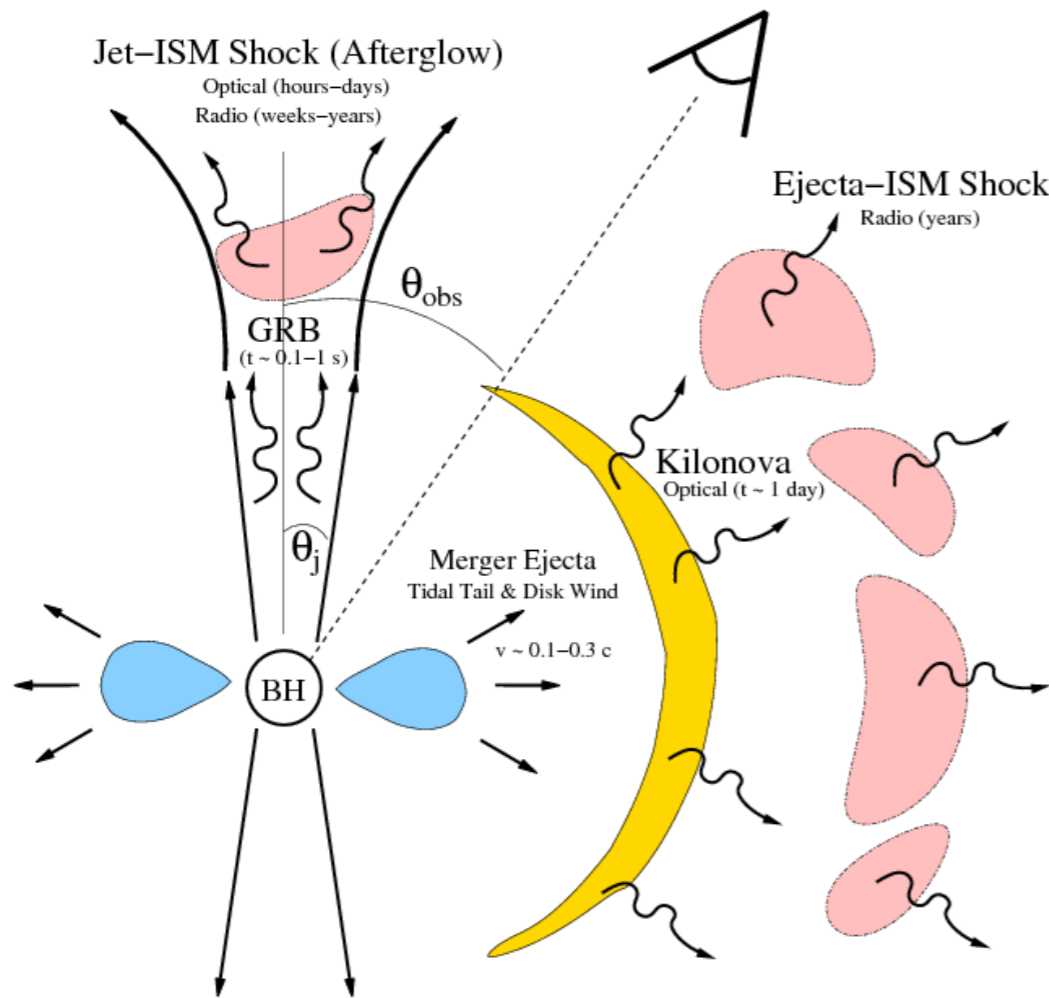
$t-t_c$ (days)

GW170817

Optical/near-infrared kilonova



Model of the electromagnetic counterpart of a binary neutron star merger



Rapid evolution of kilonova :

- peak emission shifts to long wavelengths
- faded after <10 days
- radioactive decay of neutron-rich ejecta

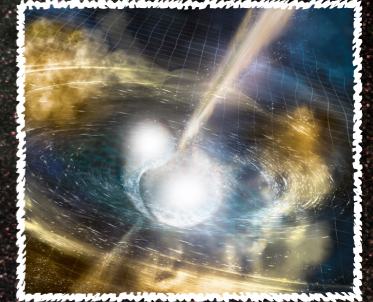
What is the Most Promising Electromagnetic Counterpart of a Neutron Star Binary Merger?

Metzger, B.D. *et al.* *Astrophys.J.* 746 (2012) 48

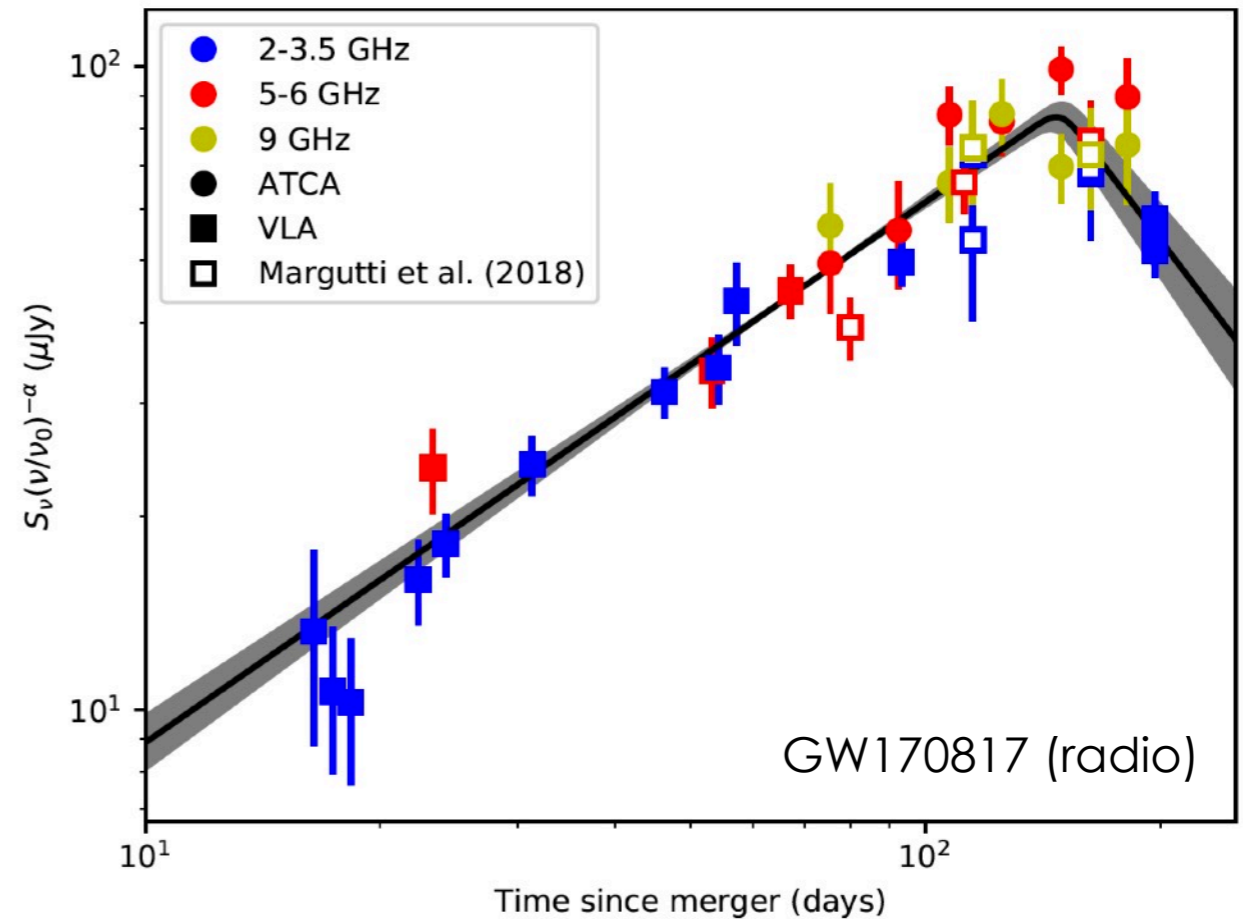
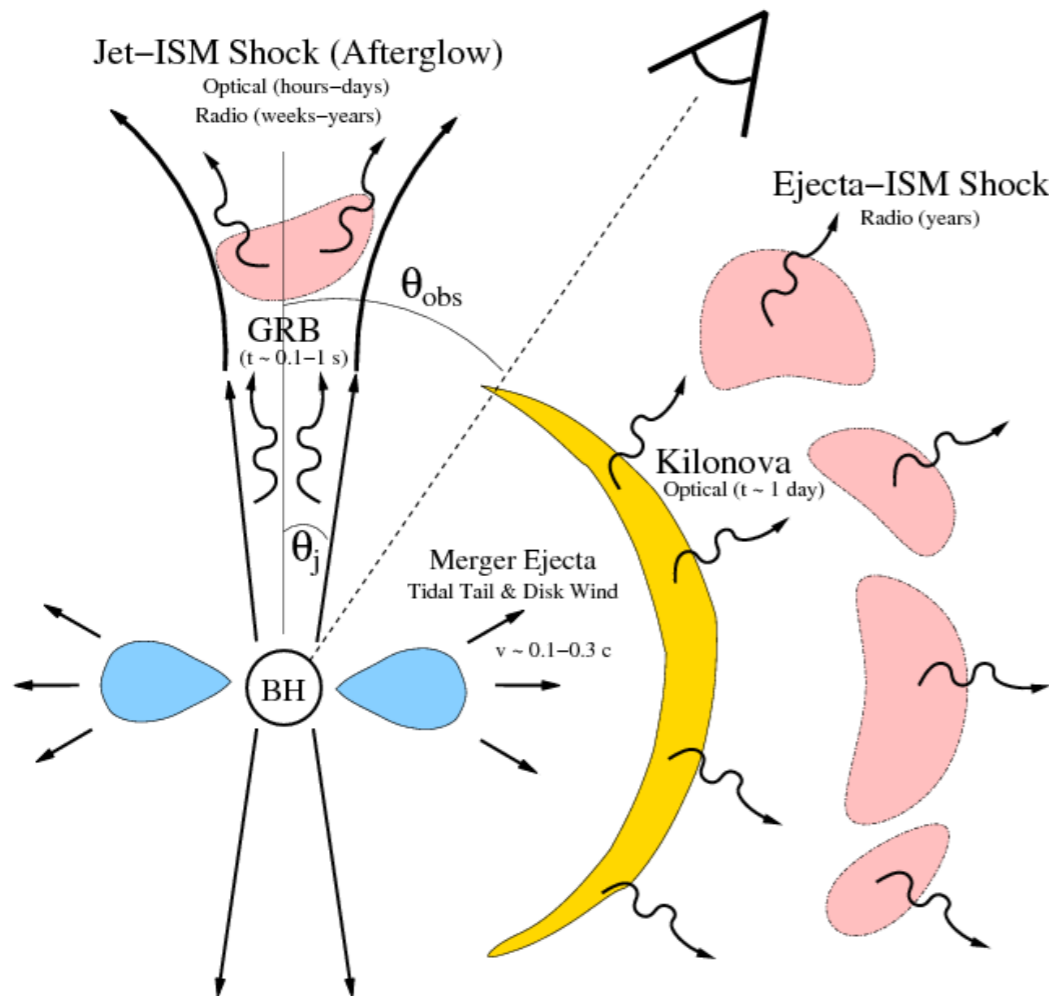


GW170817

The radio afterglow



Model of the electromagnetic counterpart of a binary neutron star merger



What is the Most Promising Electromagnetic Counterpart of a Neutron Star Binary Merger?

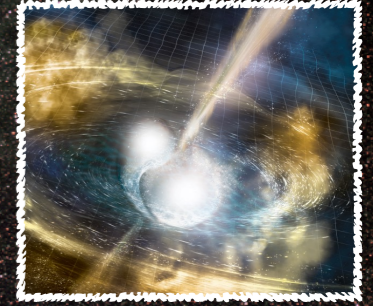
Metzger, B.D. et al. *Astrophys.J.* 746 (2012) 48

A Turnover in the Radio Light Curve of GW170817

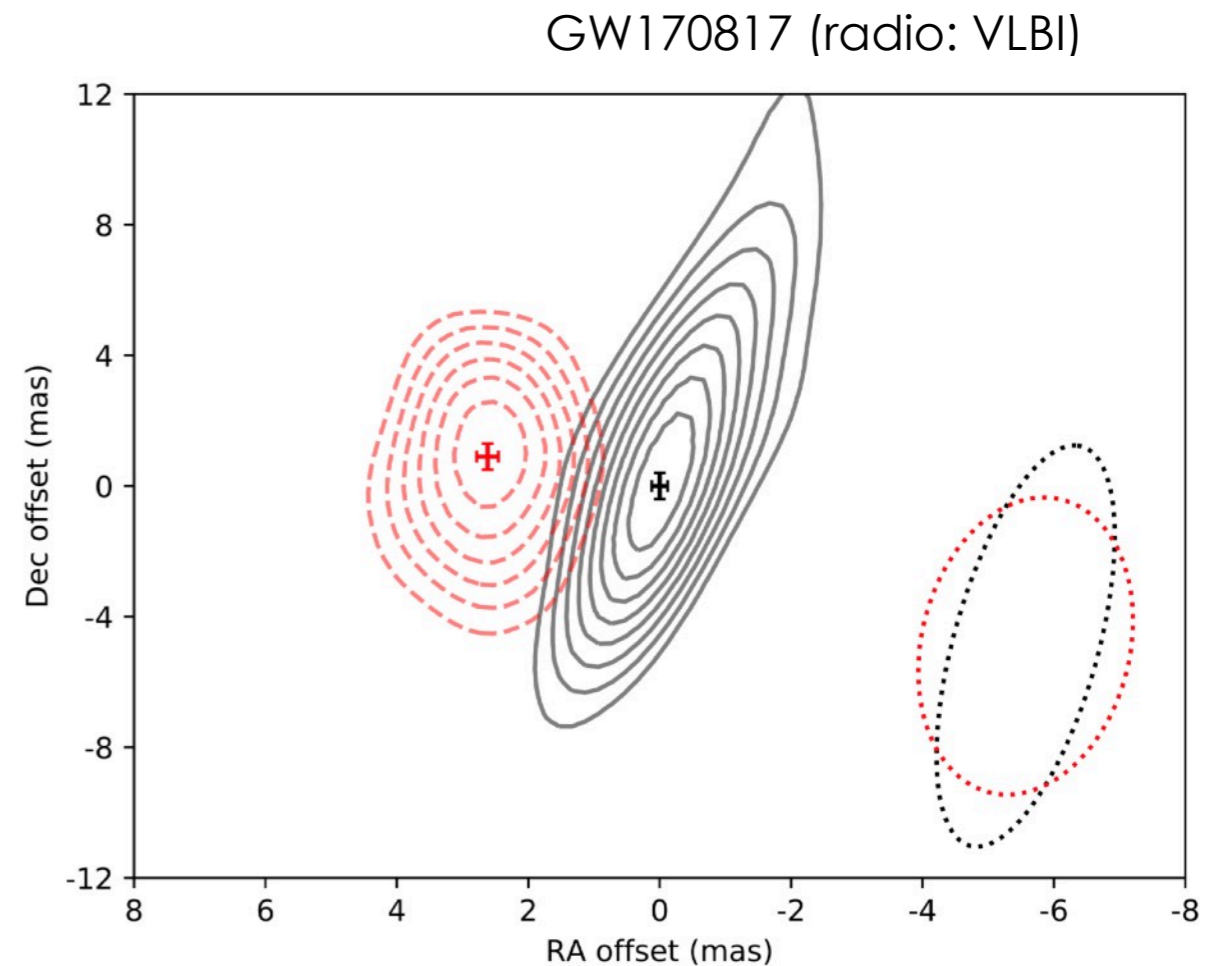
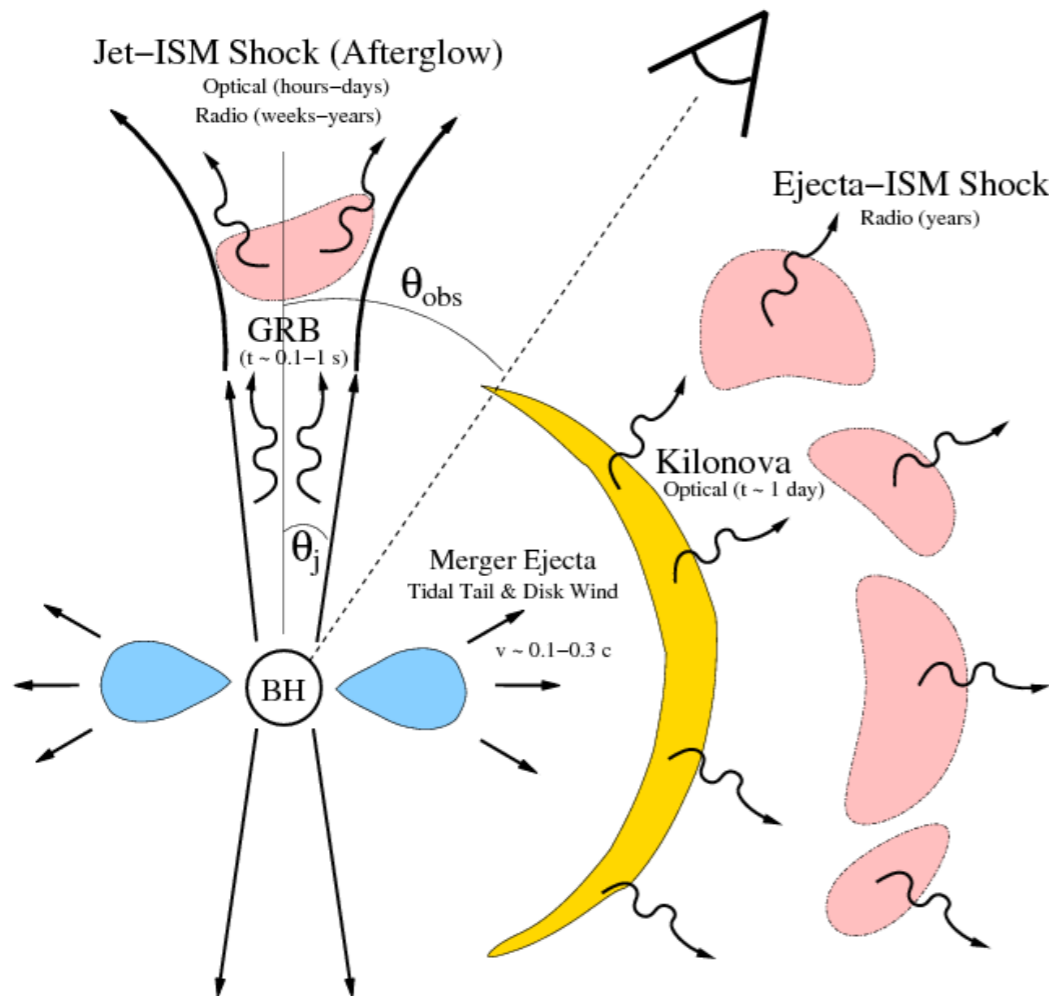
Dobie et al. 2018 [arXiv:1803.06853]

GW170817

The radio afterglow



Model of the electromagnetic counterpart of a binary neutron star merger



What is the Most Promising Electromagnetic Counterpart of a Neutron Star Binary Merger?

Metzger, B.D. et al. *Astrophys.J.* 746 (2012) 48

Superluminal motion of a relativistic jet in the neutron star merger GW170817

Mooley et al. 2018 [arXiv:1806.09693]



III - Optical Astronomy in South Africa

in support of multi-wavelength [transient] astrophysics

Telescopes at the SAAO

SALT 11-m: optical/NIR spectroscopy; fast imaging
[See talk by P. Vaisanen](#)

1.9-m - optical
optical spectroscopy

1.0-m - optical
polarimetry

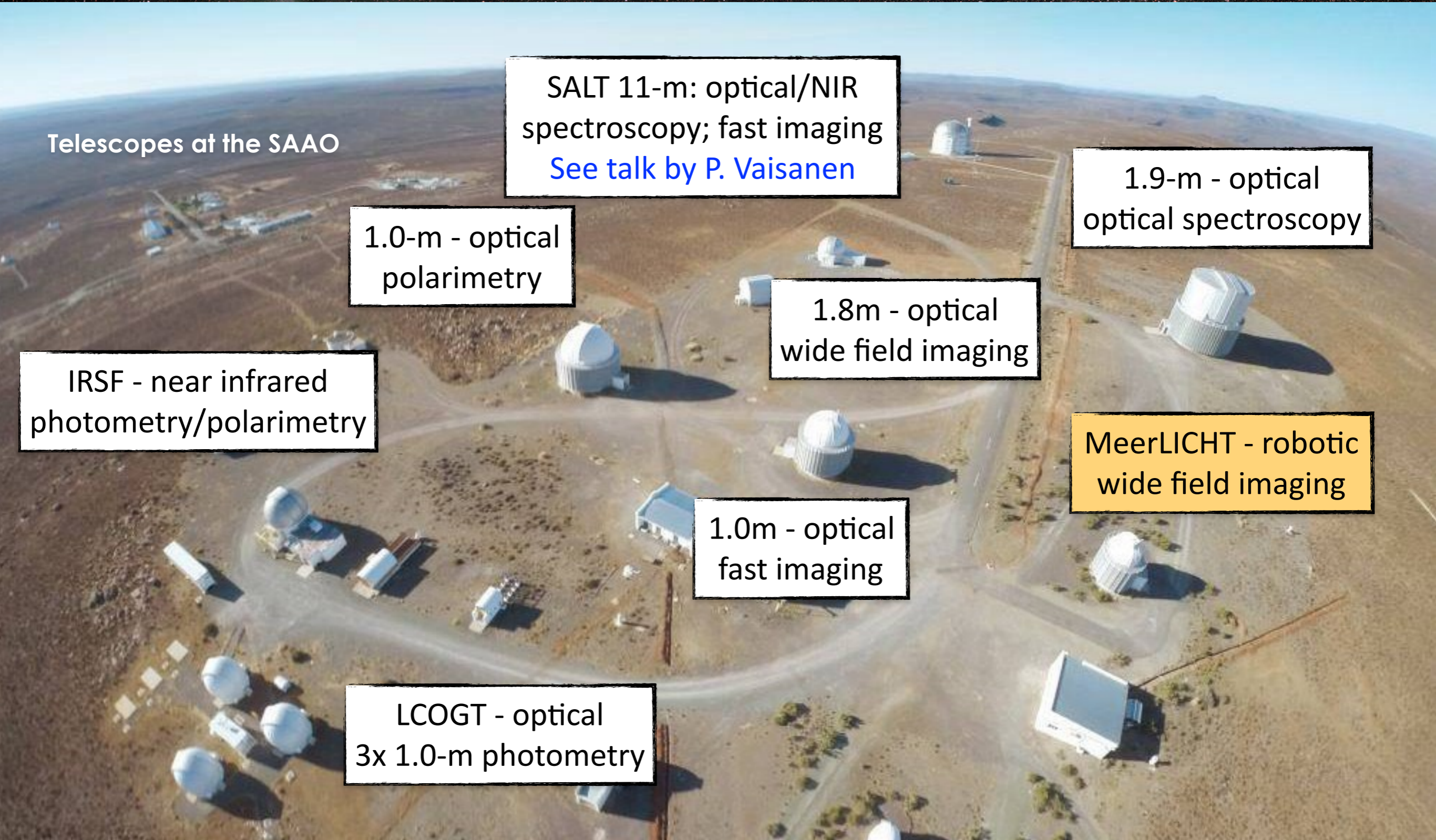
1.8m - optical
wide field imaging

IRSF - near infrared
photometry/polarimetry

MeerLICHT - robotic
wide field imaging

1.0m - optical
fast imaging

LCOGT - optical
3x 1.0-m photometry



III - Optical Astronomy in South Africa

Multi-wavelength approach to radio transients

Radio:

- Total energetics
- Jets yes/no?
- Jet flow velocities
- Magnetic field strength
- Circumstellar densities
- Relic shells
- Outflow evolution

X-ray:

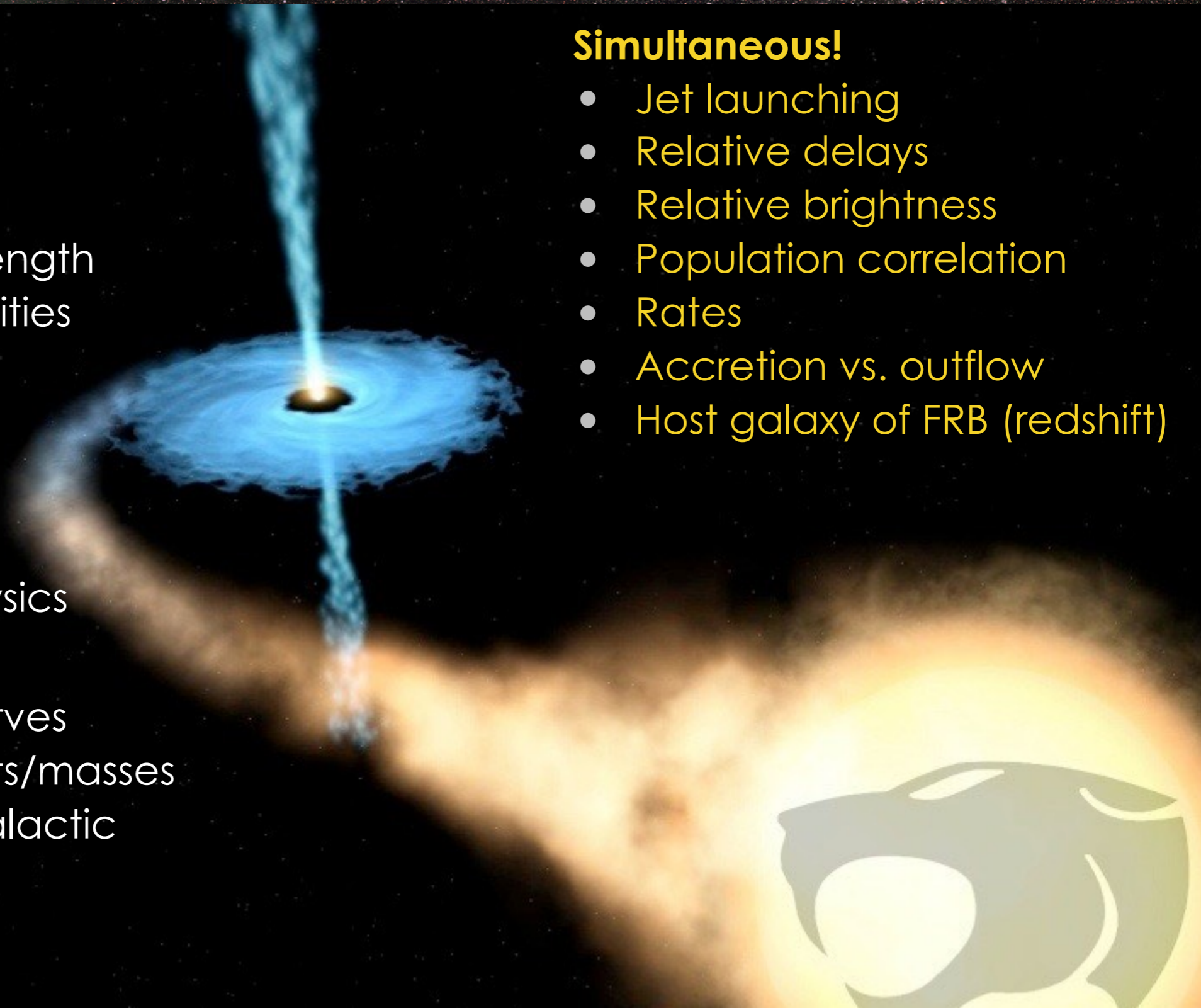
- Accretion rates
- Accretion disk physics

Optical:

- Radial velocity curves
- Binary components/masses
- Redshifts if extragalactic
- Donor stars
- Time evolution

Simultaneous!

- Jet launching
- Relative delays
- Relative brightness
- Population correlation
- Rates
- Accretion vs. outflow
- Host galaxy of FRB (redshift)



III - Optical Astronomy in South Africa

MeerLICHT [innovation in operations - commensal]

MeerKAT / South African Radio Astronomy Observatory



South African Astronomical Observatory

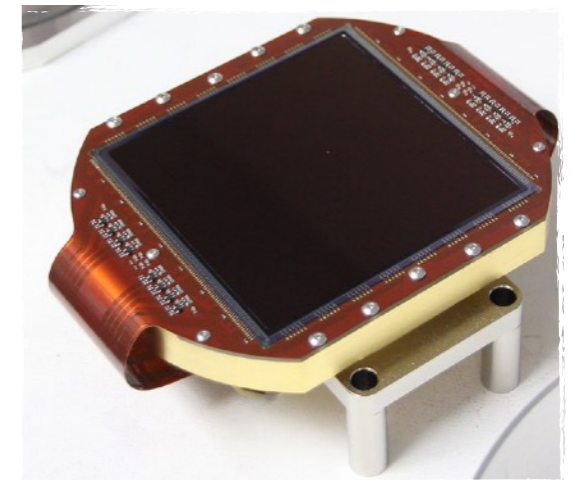
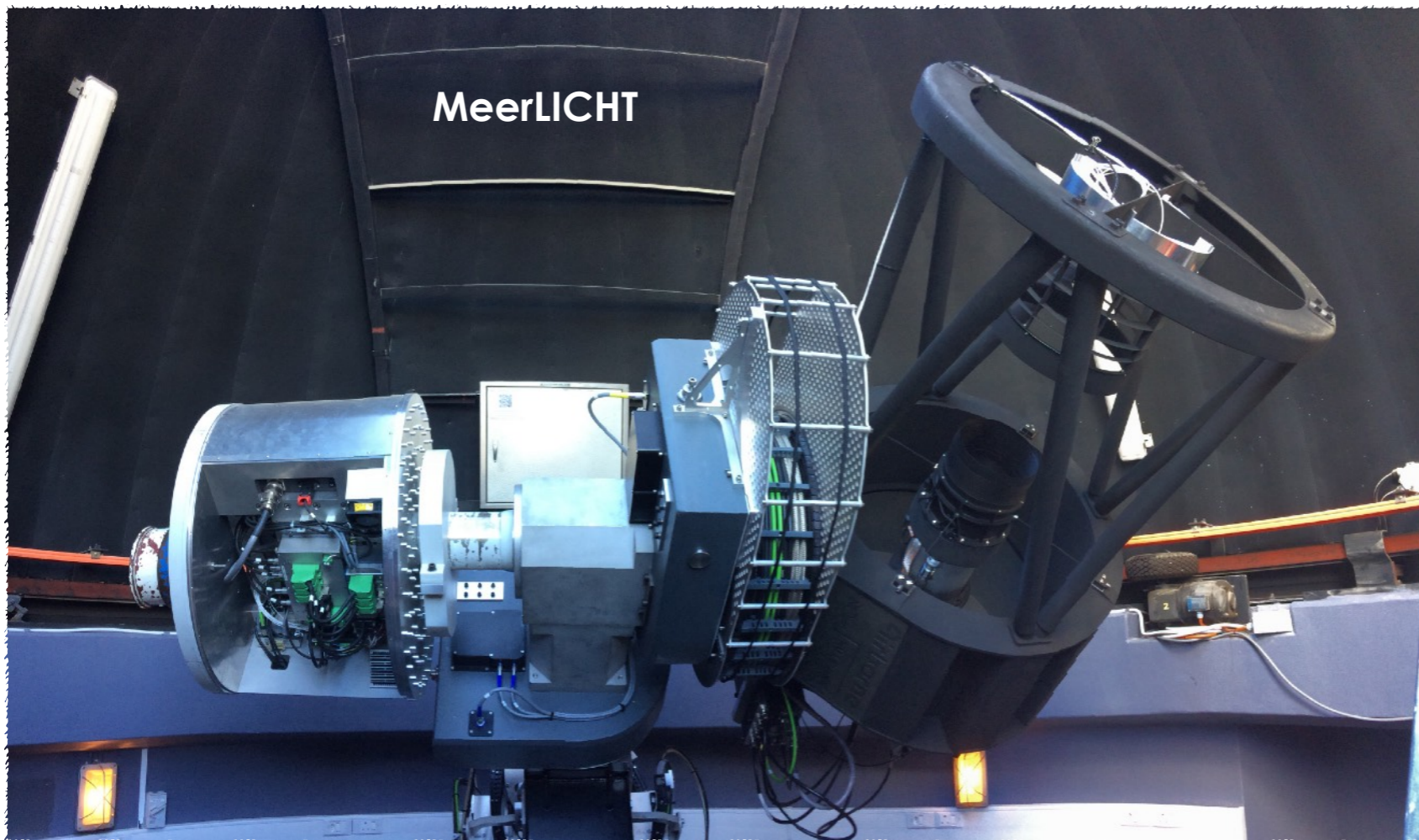


Commensal data access to MeerKAT data

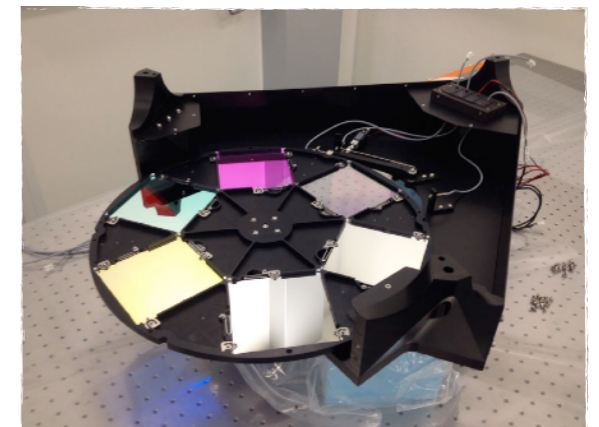
- all data can be searched for transients (ThunderKAT/MeerTRAP)

III - Optical Astronomy in South Africa

MeerLICHT [innovation in design - robotic, wide FoV]



STA chip (10.5k x 10.5k)



ugrizq filters

MeerLICHT

- Robotic telescope - wide field imager (1.7 x 1.7 degrees)
- Permanently tied to the MeerKAT observing schedule

III - Optical Astronomy in South Africa

MeerLICHT [link to data mining]

Radio:

- MeerKAT Large Survey Projects
- 70% of MeerKAT time
- **Commensal** transient search
- Time-scales: 2 sec and up
- MeerKAT open time
- 30% of MeerKAT time

Simultaneous!

- **High cadence**
(second to minutes)
- **Always on** optical-radio **wide field** synoptic survey
- Database: **big data**
- **Real-time** detections

Discovery, Validate, Classify, Characterize, Data Mine

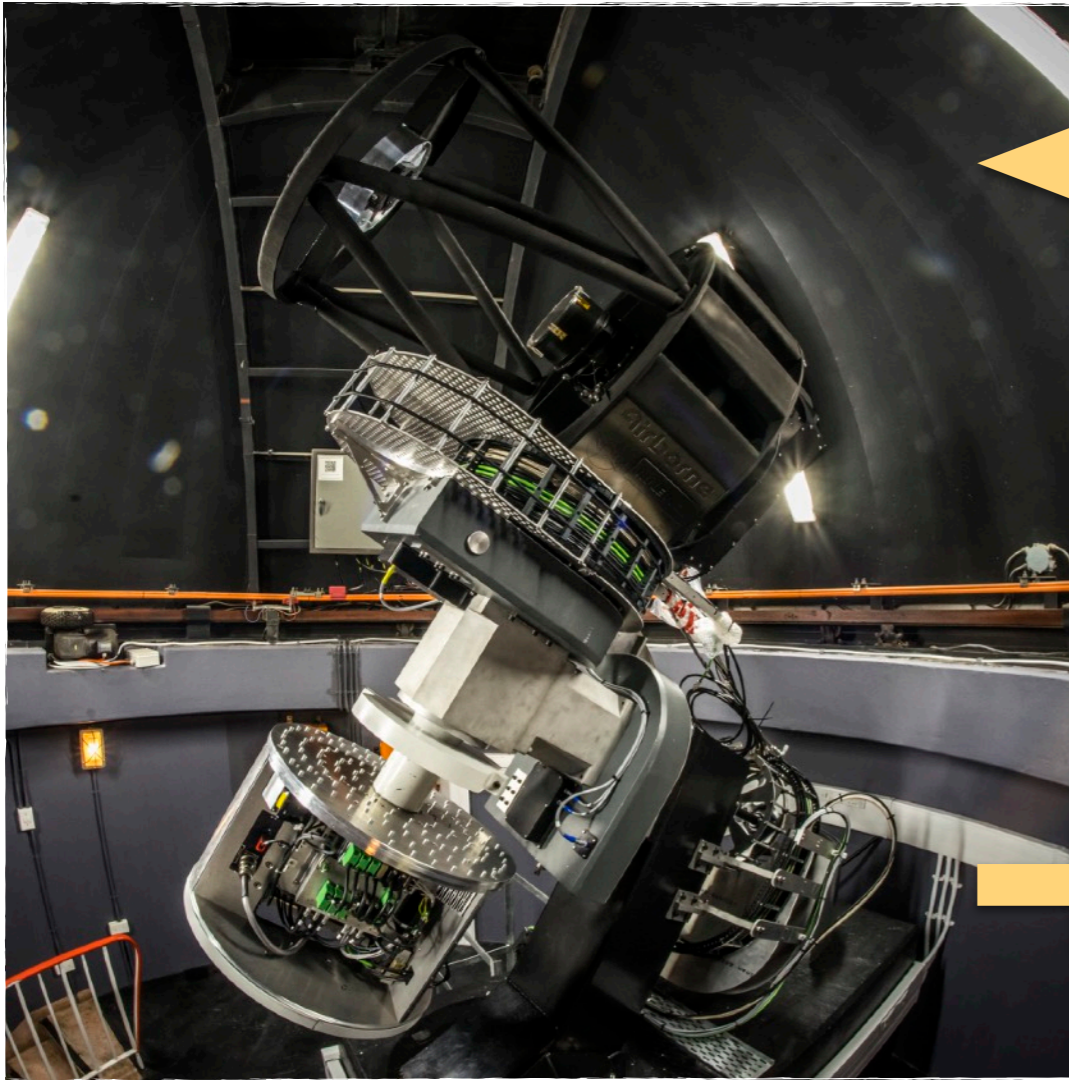
Optical:

- MeerLICHT
- Robotic 0.65-m telescope
- Synchronised to MeerKAT
- 60 sec exposures: cycle through a set of filters
- 7 sec read-out



III - Optical Astronomy in South Africa

MeerLICHT [Data-driven challenges]



MeerKAT-MeerLICHT

- MeerKAT determines observing schedule
- Data fusion at IDIA: transient searches / VOEvents

III - Optical Astronomy in South Africa

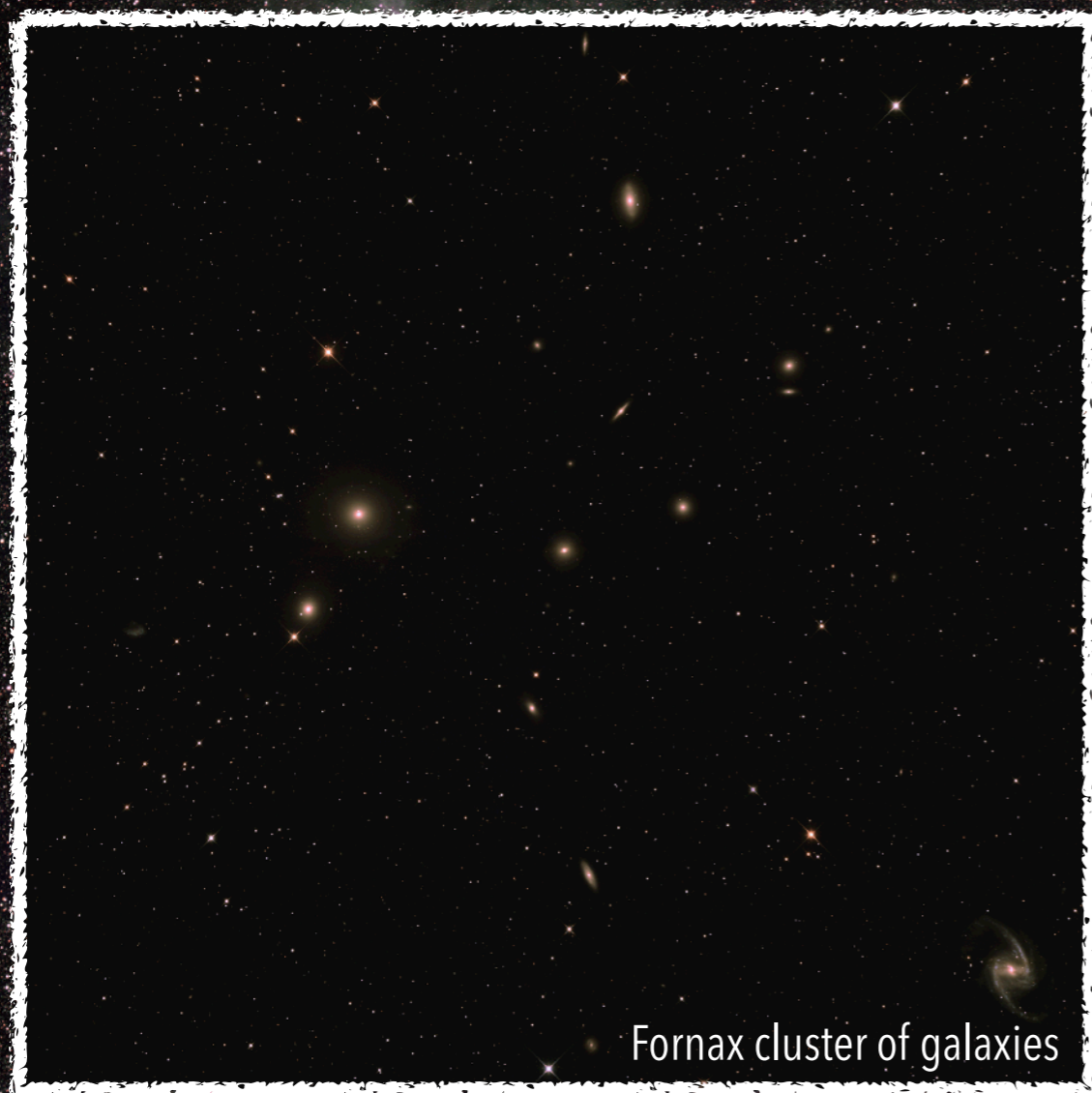
MeerLICHT [Inauguration on Africa Day 2018]



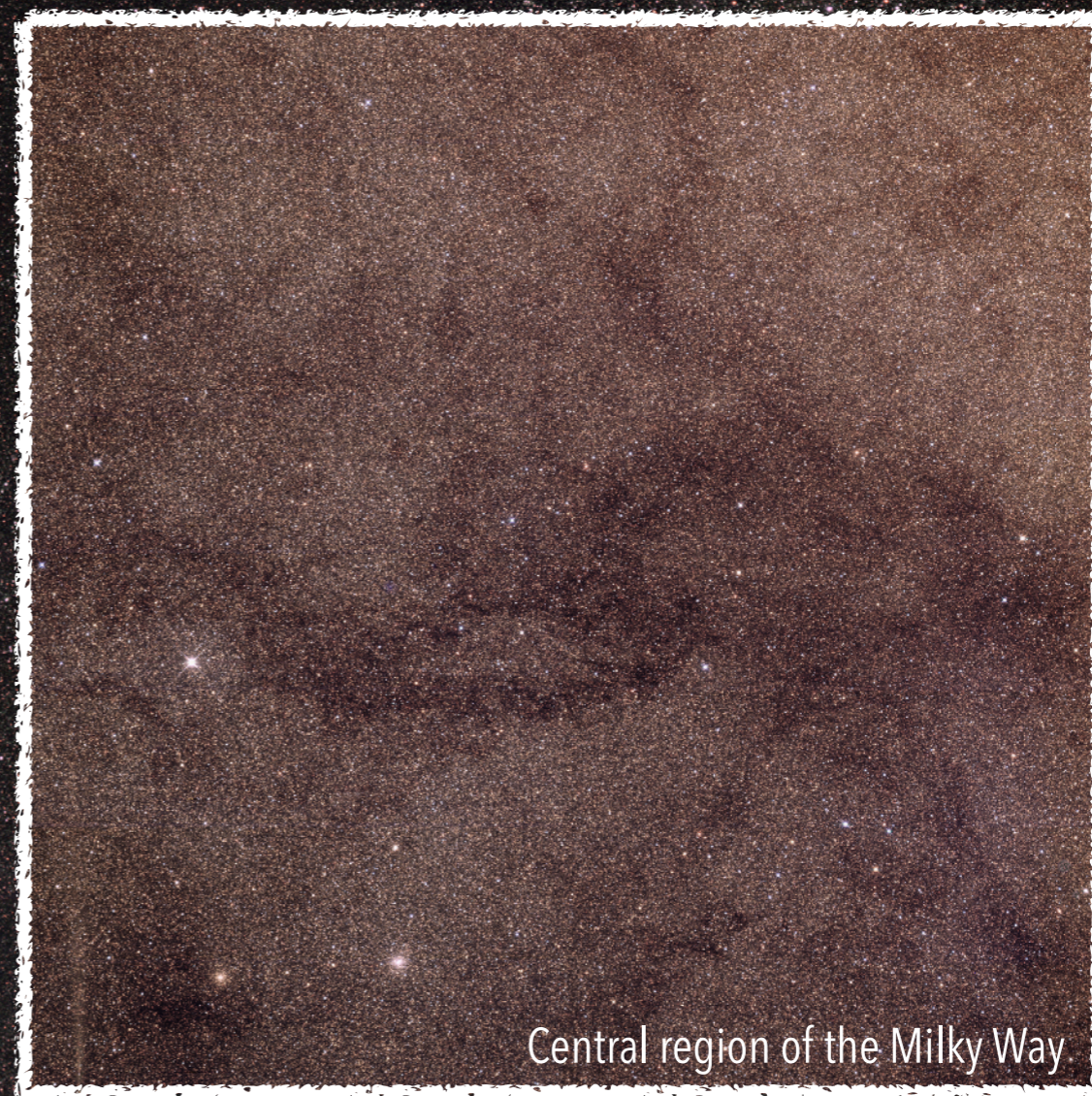


← Neutrinos were here (SN1987A)

First light images from MeerLICHT



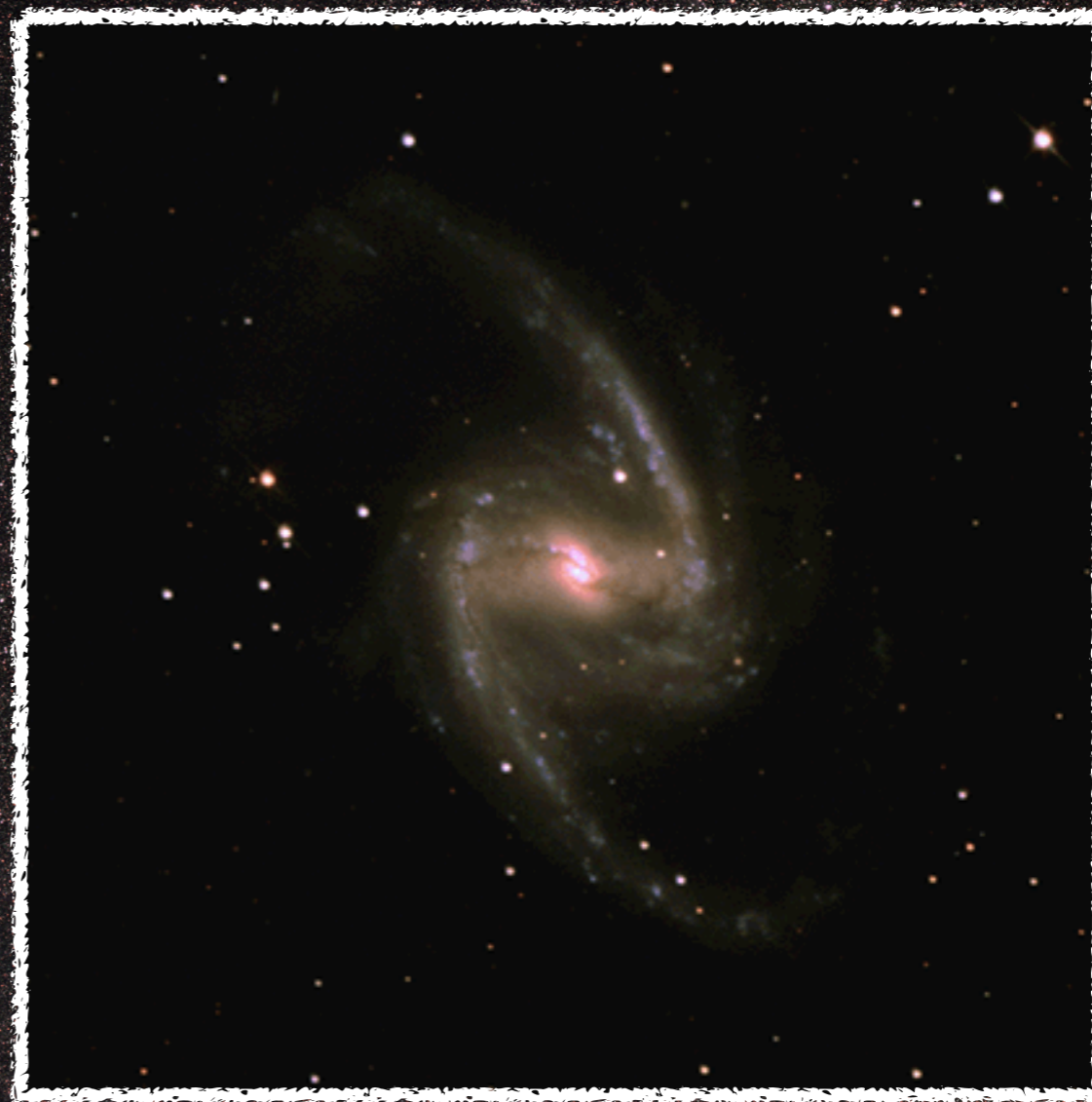
Fornax cluster of galaxies



Central region of the Milky Way

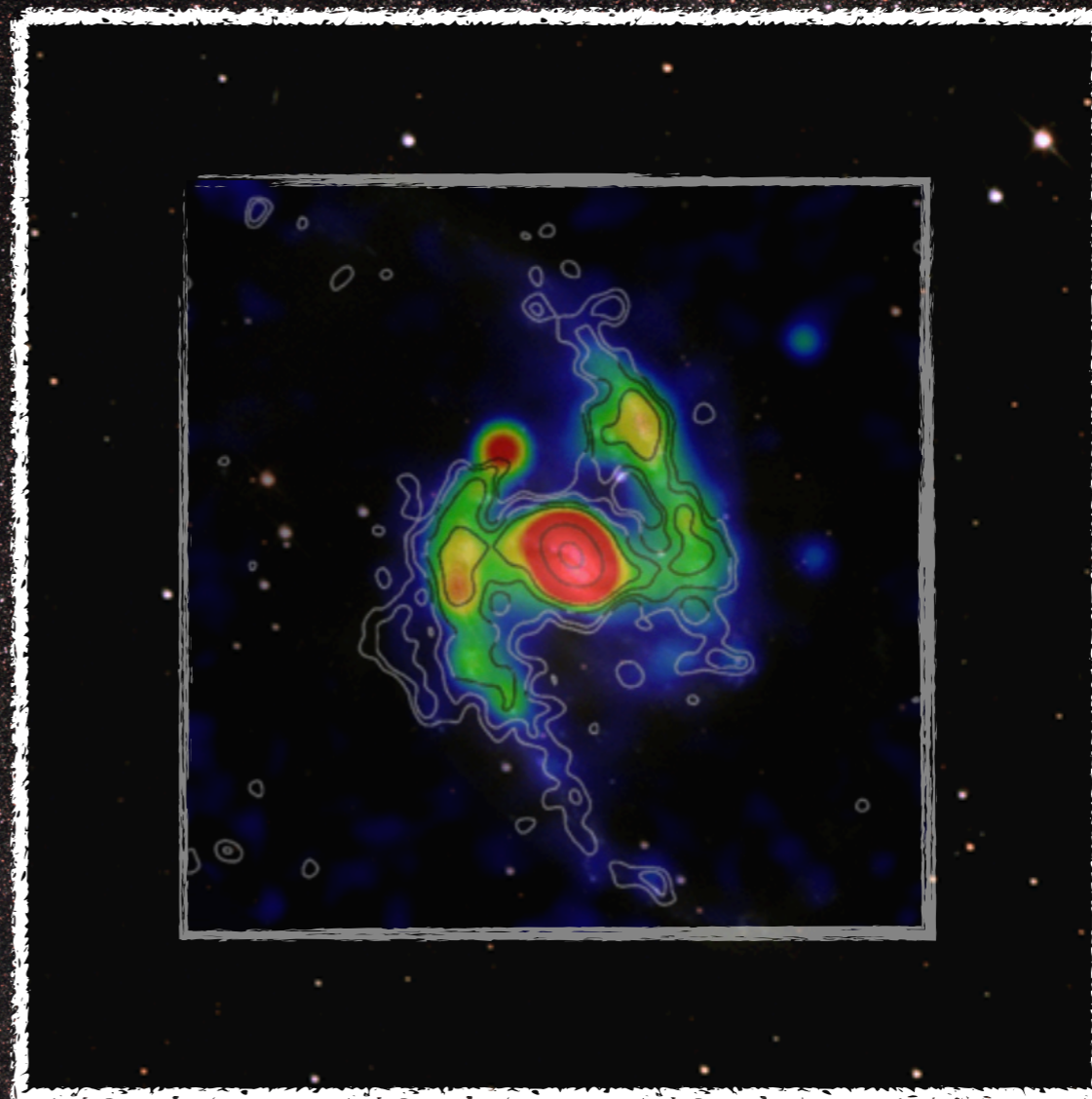
MeerLICHT

connecting wavelengths, connecting communities



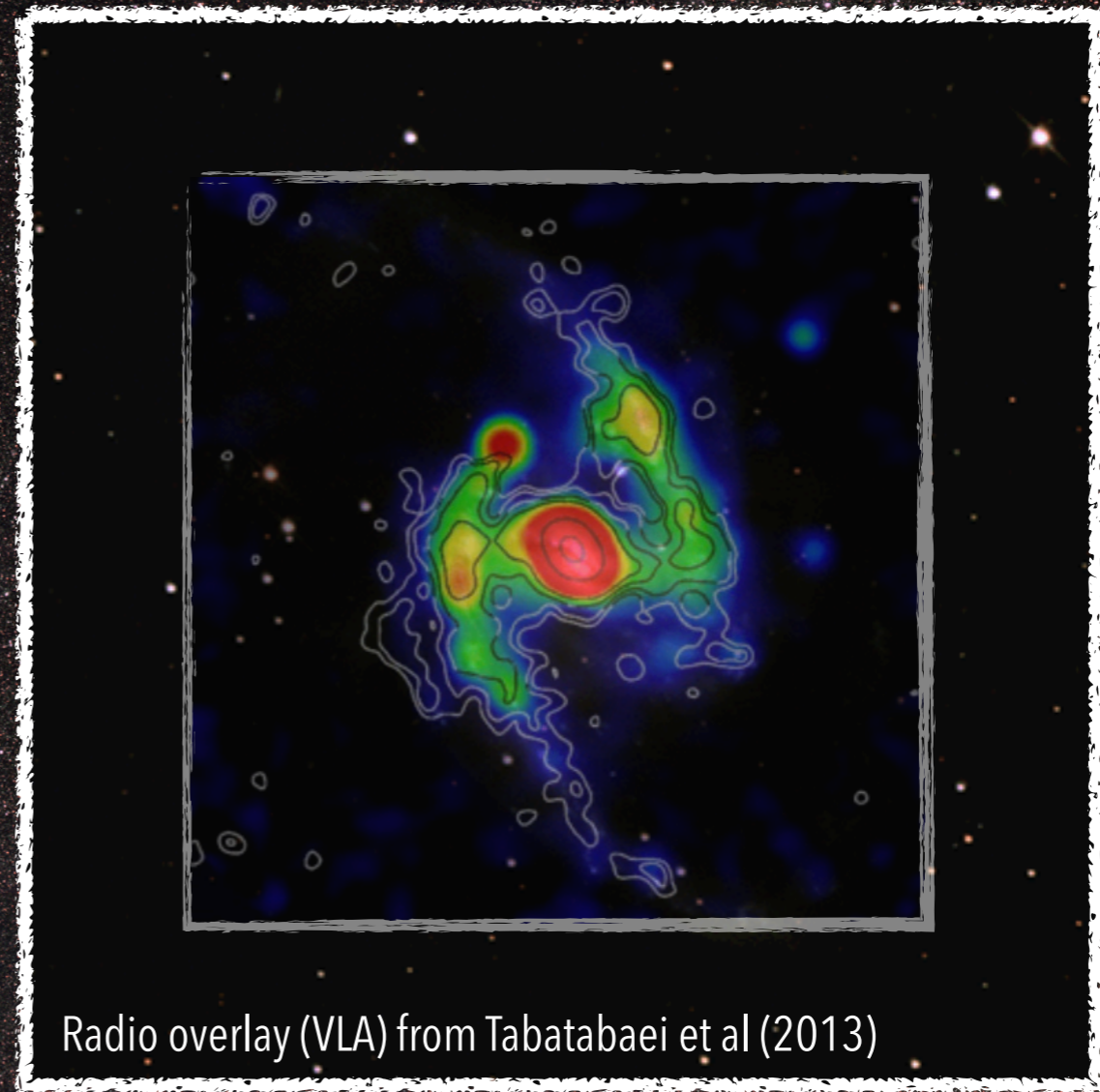
MeerLICHT

connecting wavelengths, connecting communities



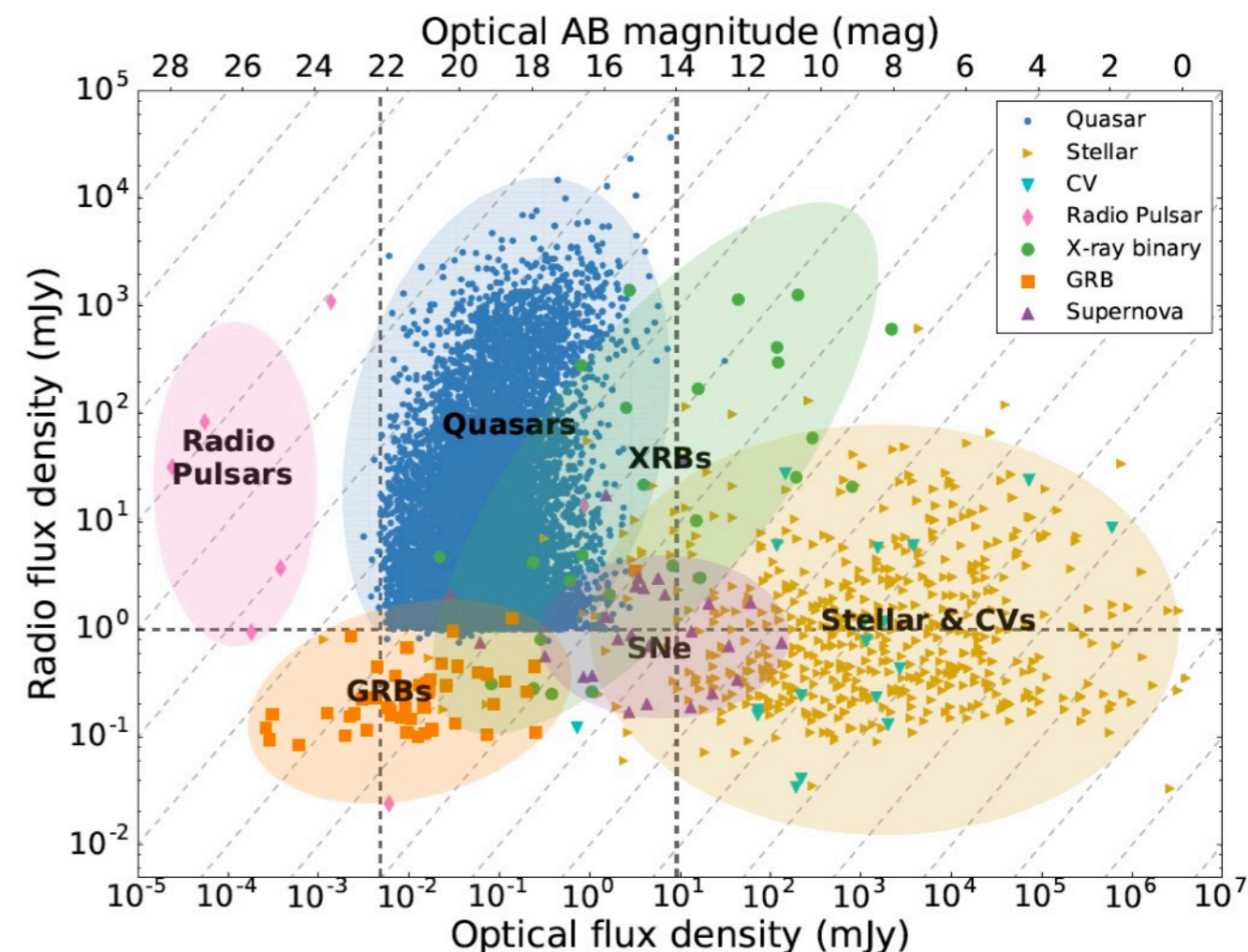
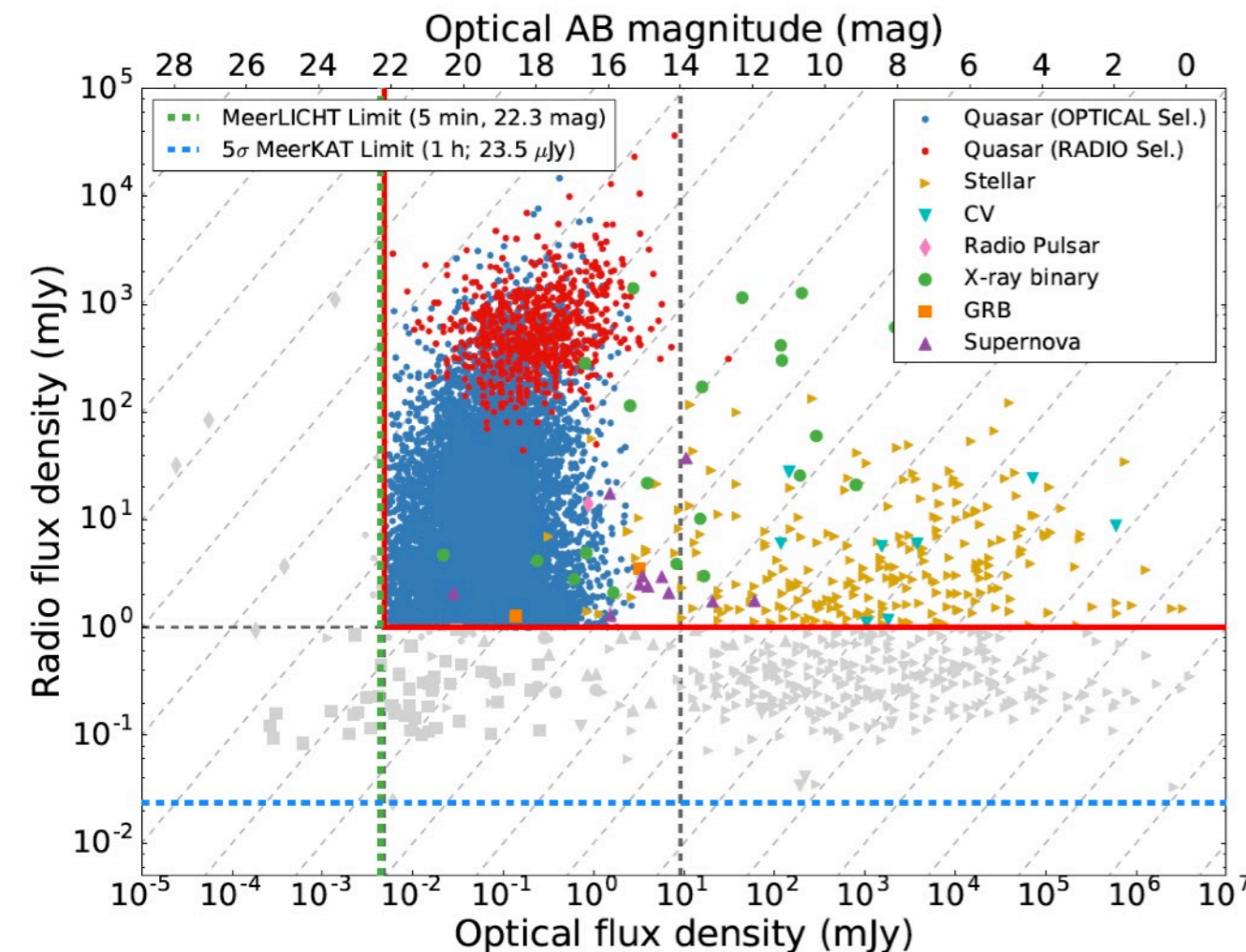
MeerLICHT

connecting wavelengths, connecting communities



III - Optical Astronomy in South Africa

MeerKAT/MeerLICHT and machine learning



On the optical counterparts of radio transients and variables. Steward et al. 2018 [arXiv:1806.09915]

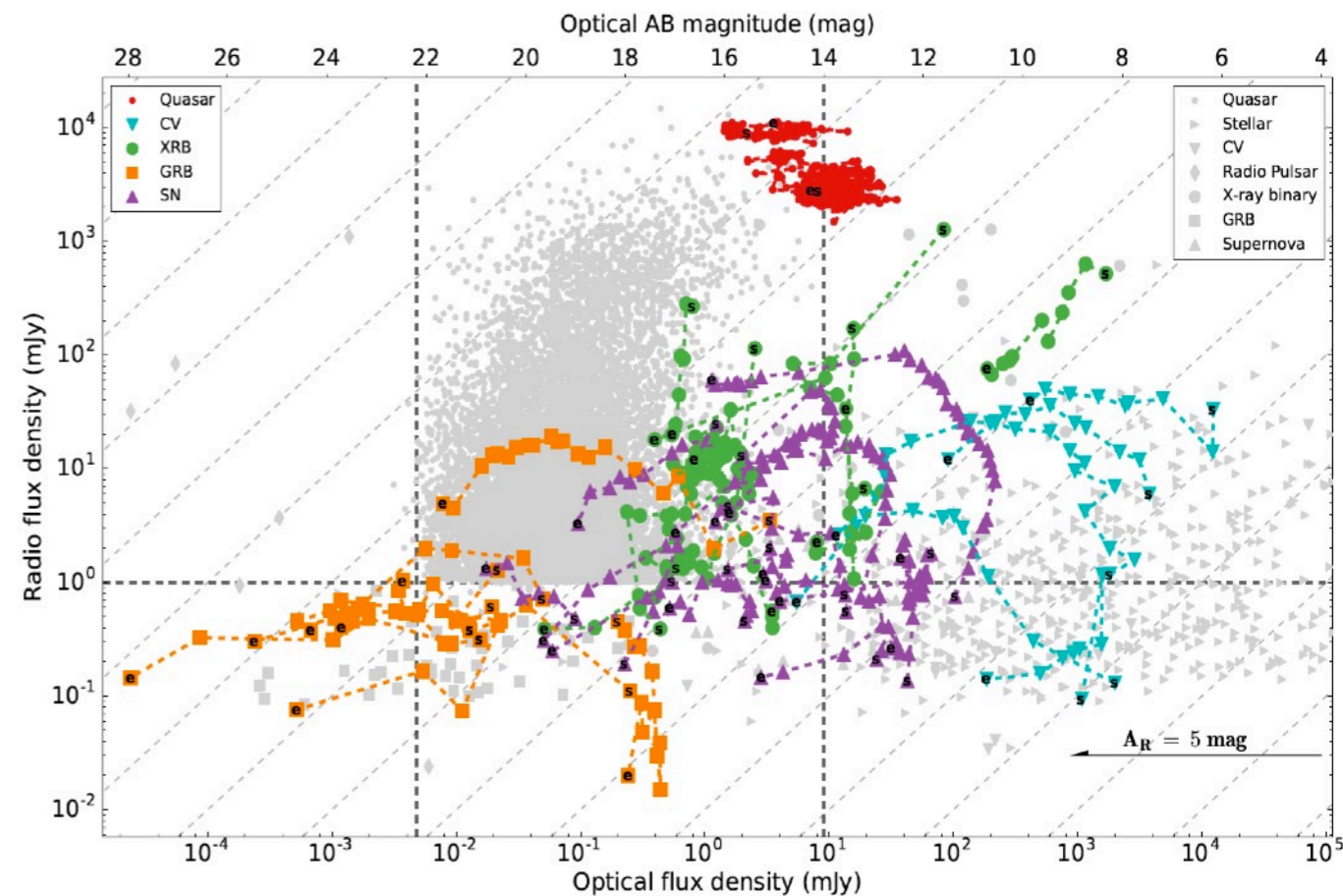
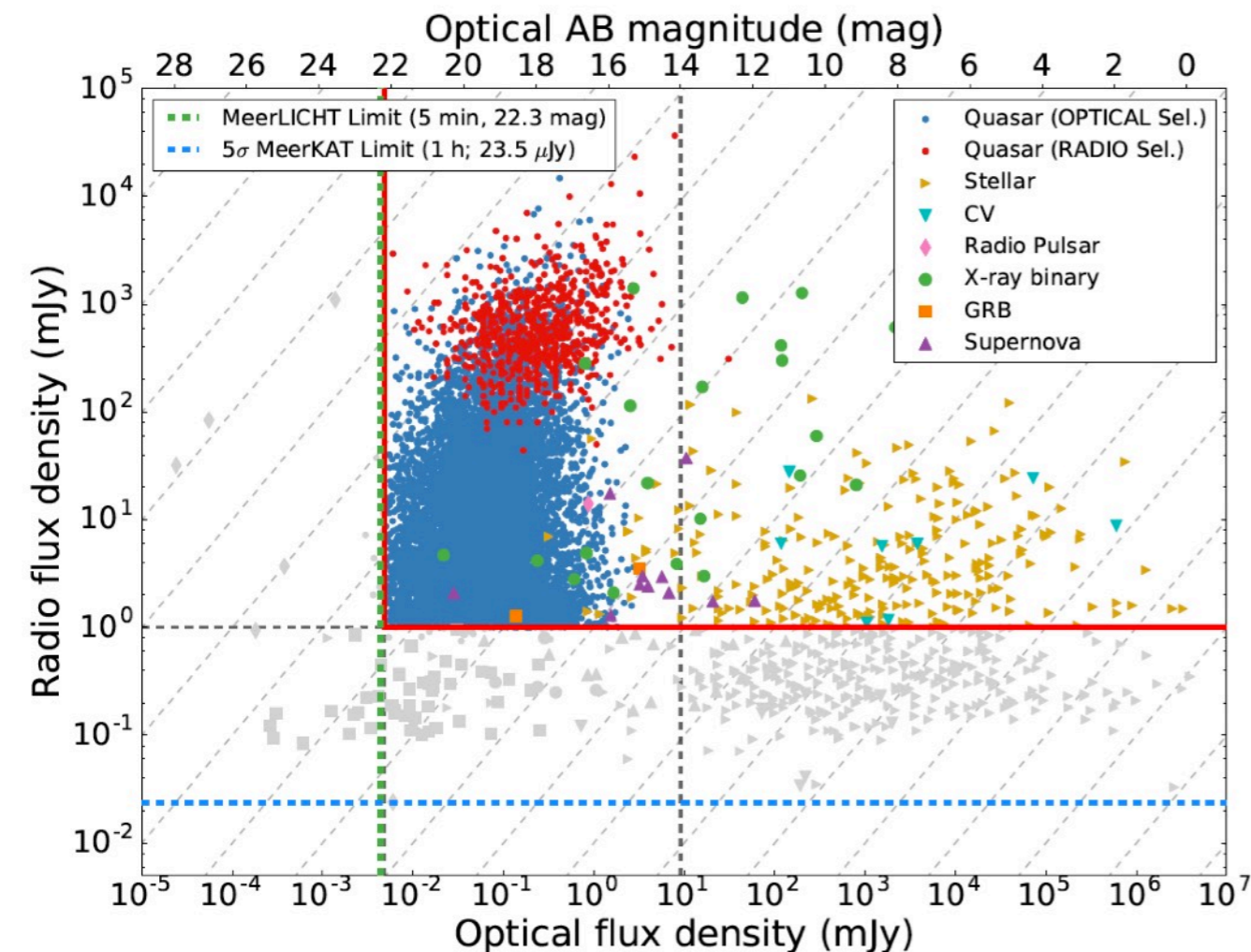
Machine learning:

- real-time classification of radio/optical transients



III - Optical Astronomy in South Africa

MeerKAT/MeerLICHT and machine learning



On the optical counterparts of radio transients and variables. Steward et al. 2018 [arXiv:1806.09915]

Machine learning:

- real-time classification of radio/optical transients



Optical Astronomy in South Africa

Closing perspectives

Tremendous growth of the astronomical community in South Africa

- Successful Human Capacity Development programs
- National Strategy for Multi-wavelength Astronomy

SKA - a global flagship science facility in Africa

- MeerKAT as a pathway to SKA1-MID
- MeerKAT science to benefit the development of physics in Africa (AVN)
- Links to Big Data / Machine learning

Optical Astronomy in South Africa

- Optical astronomy firmly integrated in multi-wavelength strategy
- MeerLICHT: an innovative project to maximise MeerKAT science

ICPE2018 advertisement

Physics Education for Development: A focus on context



International Conference on Physics Education

Co-hosts: The South African Institute of Physics, University of the Witwatersrand and The International Commission on Physics Education (C14) of the International Union of Pure and Applied Physics

Conference Theme: "Physics Education for Development: a focus on context" across eleven tracks

Abstract Submission and Registration Key Dates

Deadline for Abstract Submission	:	Extended to Sunday, 22 July 2018
Notification of Abstract Acceptance	:	Extended to Tuesday, 31 July 2018
On-line Registration and Accommodation	:	Open

Webpage: <http://events.saip.org.za/event/ICPE-SAIP-WITS-2018>

Enquiries: If you have any queries, please email: ICPE2018@saip.org.za