BRICS Astronomy and the Flagship Programme

The BRICS Intelligent Telescope and Data Network

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Lead Investigator
&
South African Co-Principal Investigator

Importance of Astronomy

- **Answers fundamental questions on the origins of the universe and humanity's place in it.**
- **It is a driver of innovation and an important catalyst for scientific and technological development**
- **It can enthuse young minds in science & technology**
- **It is a gateway science for outreach and tool for socio-economic development**

Background - BRICS Astronomy Working Group (BAWG)

- 1st BRICS Science, Technology and Innovation (STI) Ministerial Meeting held in Cape Town on 10 February 2014 – identified 5 thematic science priority areas:
  - Prevention and mitigating of natural disasters – Brazil
  - Water resources and pollution treatment – Russia
  - Geospatial technology and its applications – India
  - New and renewable energy, and energy efficiency – China
  - **Astronomy – South Africa**

- 2nd BRICS STI Ministerial Meeting in March 2015 in Brazil - signed a (MoU) on STI cooperation. This MoU makes provision for three governing structures:
  - BRICS STI Ministerial Meeting
  - BRICS STI Senior Officials Meeting
  - **BRICS STI Working Groups – expert groups in each of the thematic areas**
    - **BRICS Astronomy Working Group (BAWG)**

- 3rd BRICS STI Ministerial meeting held in October 2015 in Moscow - Work Plan was adopted

BAWG Purpose and Role

- **The BAWG is:**
  - responsible for promoting cooperation activities in the astronomy priority area;
  - convenes BAWG meetings and workshops at least once a year;
  - composed of government officials, focal points (astronomy institutions) and experts; and
  - chaired by the South African Department of Higher Education, Science and Technology (DHEST) which provides secretariat support.

- **As the Secretariat, South Africa:**
  - **provides administrative support to the BAWG and its programmes;**
  - **coordinates the networking of the BRICS astronomy communities to get to know each other and work together;**
  - Facilitates development of content and ensures follow-up on actions;
  - captures and maintains proceedings/resolutions of the BAWG; and
  - disseminates information to the astronomy communities using various media(email, etc) including a website - http://www.bricsastronomy.org

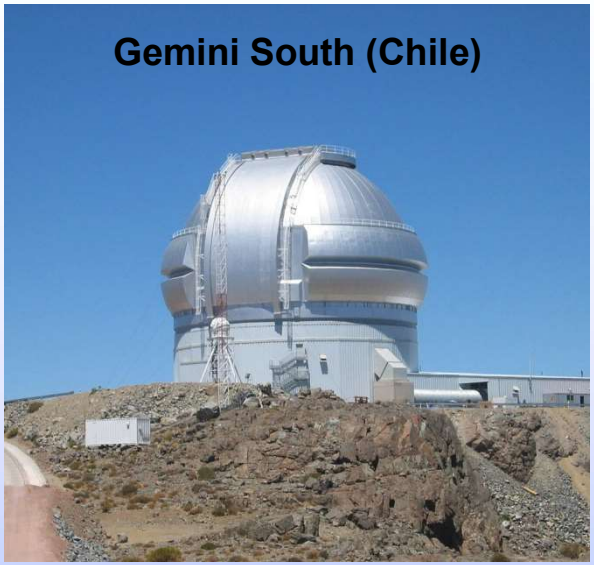
BRICS Astronomy Goals

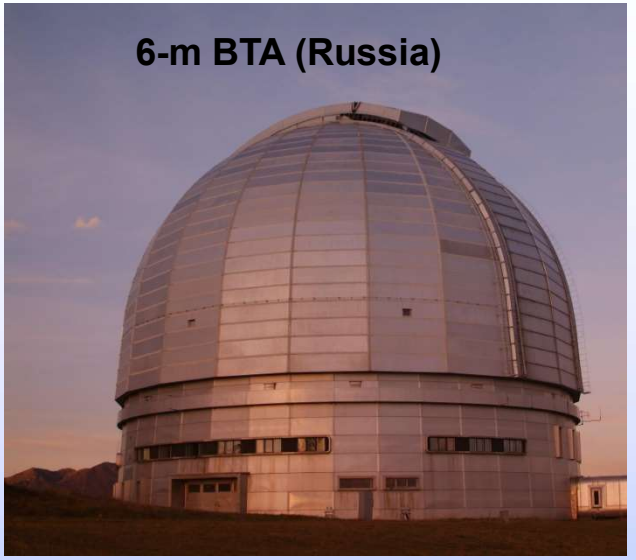
- **Common aspirations for scientific and technological advancement through collaboration**
- **Enhancing human capital development and wider benefits to our societies**
- **Leveraging existing and future facilities within BRICS *or for which BRICS has access***
- **Develop an internationally competitive astronomy programme – a "flagship" – the *BRICS Intelligent Telescope and Data Network***
- **Focus on the enormous potential of the big astronomy survey programmes of the next 2 decades and the enourmous data and compute challenges they bring:**
  - **Optical: *The Rubin Observatory Legacy Survey of Space and Time (LSST)***
  - **Radio: *The Square Kilometre Array (SKA)***

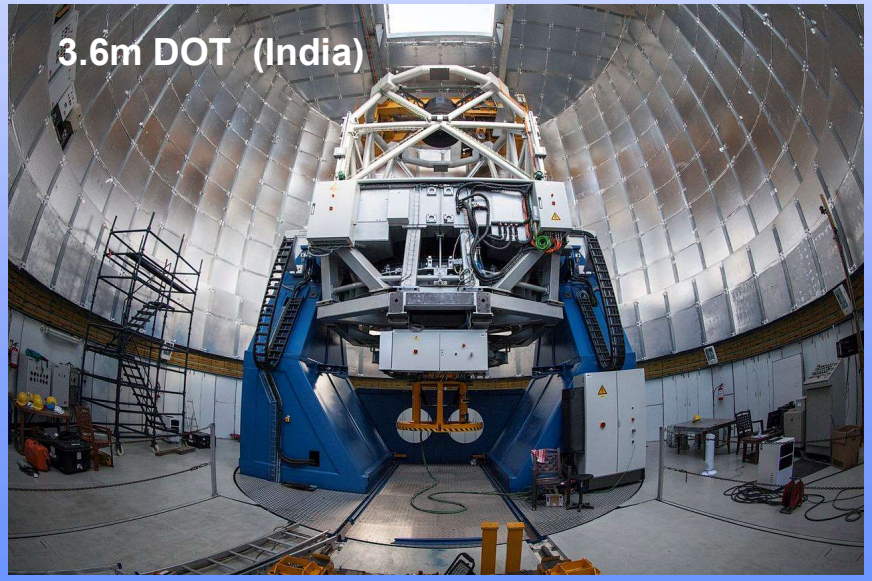
Rubin Observatory's *Legacy Survey of Space & Time* (LSST)

The *Square Kilometre Array*

Exploit Existing BRICS Facility Access







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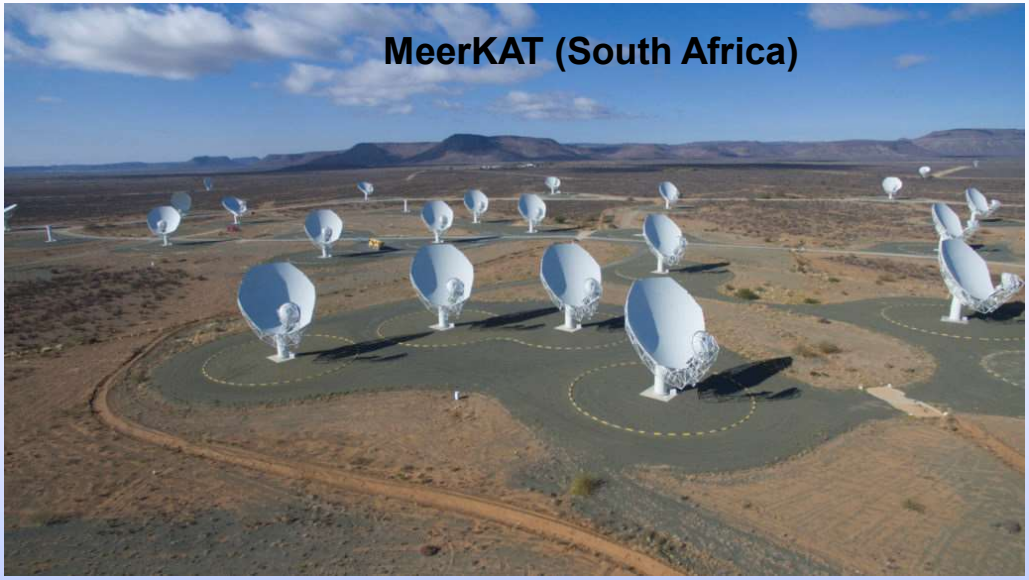
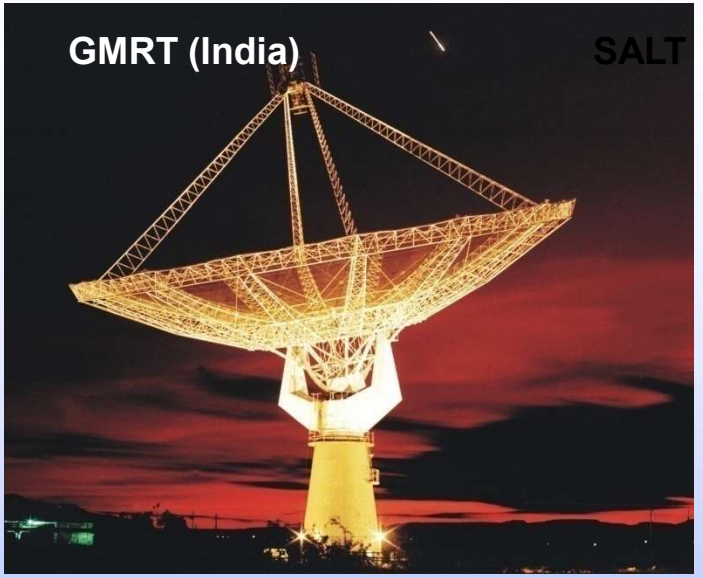
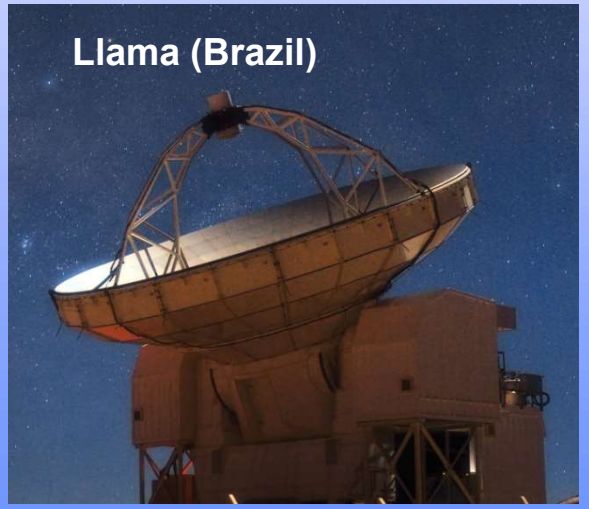
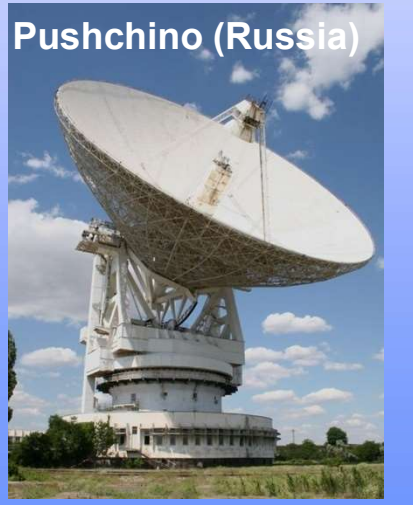








BRICS Facilities

- **Synergies with other astronomical facilities in BRICS countries**
  - **Brazil: access to 4.0-m SOAR optical telescope and European Southern Observatory, radio dishes**
  - **Russia: access to many optical telescopes (1 to 6-m) and RATAN radio telescope**
  - **India: 3.5-m ARIES and smaller optical telescope; 4-m liquid mirror, GMRT radio array**
  - **China: FAST radio dish (largest in the world), LAMOST 6-m, plus 1 & 2-m optical telescopes**
  - **South Africa: SALT 10-m, 1-2 m optical telescopes, MeerKAT, Square Kilometer Array**

- **Telescope distributed in longitude and latitude**
  - **Allow access to a wide area of sky continuously**

History of the Flagship Programme

- **BRICS astronomy program began with projects under *Science, Technology & Innovation (STI)* program**
  - » **Limited to 2 – 3 years**
  - » **Mostly supporting reseach collaboration travel & meetings**
  - » **Modest funding (e.g. $20k / year / partner)**
- **Adoption at Sep 2017 BAWG in Pune of a call for BRICS "flagship" astronomy projects**
  - – **Should be compelling and competitive science**
  - – **Ideally involve most BRICS countries**
  - – **Call announced in early 2018 for proposals**
- **Presentations of the 18 "concept notes" proposals at the Oct 2018 BAWG in Durban**
- **Task Team was appointed to review**

History of the Flagship Programme

Criteria for selection of viable concept proposals

1. *Appropriateness in terms of a flagship project rather than one which could be funded through the existing ~3yr STI Framework Programme*
2. *Science impact, international competitiveness and uniqueness*
3. *Potential for participation amongst most/all of the BRICS countries*
4. *Socioeconomic benefits, particularly in terms of human capacity development*
5. *Alignment with developments within 4th industrial revolution paradigm*
6. *Potential for private sector involvement*
7. *Potential to leverage existing and planned national facilities*
8. *Alignment with national priorities*
9. *Ability for the projects to be developed in a phased approach appropriate to funding cycles*

Three *obvious themes,* somewhat expanding the scope of the concept proposals, were then developed into full proposals:

1. **An optical transient network (3 concept props) *-> Buckley et al.***
2. **Big data infrastructure in era of large surveys like SKA & LSST (4 concept props) *-> Taylor et al.***
3. **Neutral hydrogen (21 cm) cosmology (3 concept props) *-> Ma et al.***

These 3 proposal were formally presented at the 2019 BAWG meeting which recommended adopting a merged proposal of #1 & #2 given obvious synergies

Opportunities

- **Synergies with existing and future developments**
- **Huge opportunity for young researchers & students**
  - postdoc fellowships
  - postgraduate scholarships
  - Co-supervision with other BRICS partners
  - annual meetings & workshop
- **Technical collaboration opportunities**
  - Telescopes & instruments
  - 4IR, software, machine learning, articial intelligence
  - Cyber infrastructure for Big Data & Compute
- **Wider benefits to science and society**
- **Phased approach with potential to expand as funding allows**
  - Utilize exiting telescope facilities within BRICS
  - Spend initial effort on networking telescopes to allow for more efficient response to alerts
  - Automated scheduling through event brokers (as with *LSST*) and TOMs/marshalls that decide on appropriate “what & how” of follow-up (e.g. as with *Growth/ZTF*)
  - Quite a challenge for heterogeneous collection of telescopes, but tractable

BITDN: a cast of many!

Lead Investigator

David A. H. Buckley
South African Astronomical Observatory, South Africa

Country Co-Principal Investigators

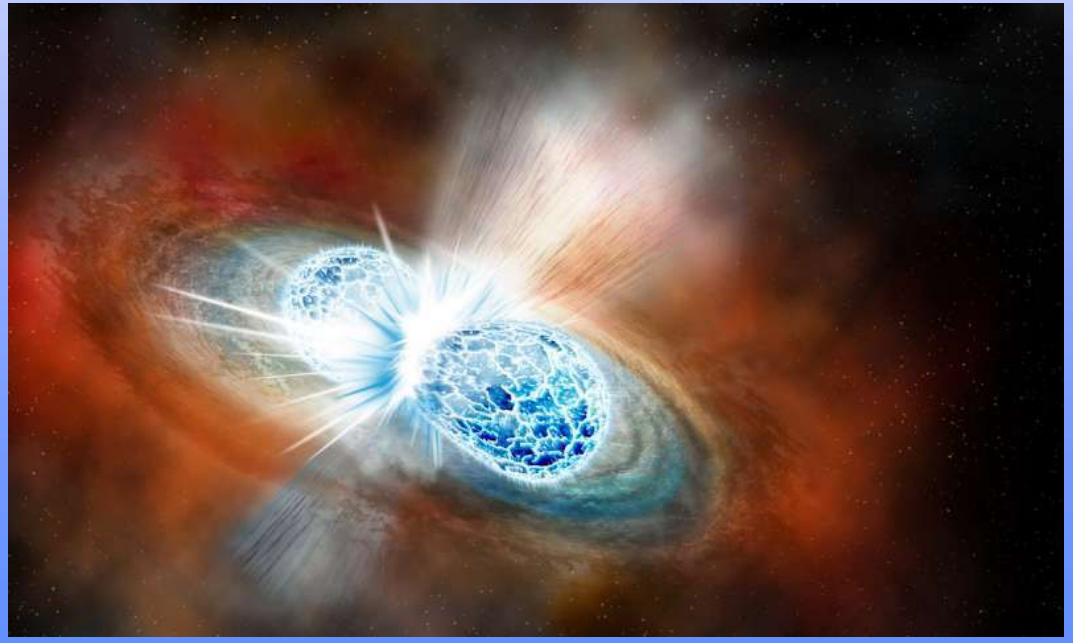
Ulisses Barres de Almeida	Centro Brasileiro de Pesquisas Físicas	Brazil
Fabio Porto	National Laboratory for Scientific Computing	Brazil
Boris Shustov	Institute of Astronomy, Russian Academy of Sciences	Russia
Oleg Malkov	Institute of Astronomy, Russian Academy of Sciences	Russia
Amitesh Omar	Aryabhatta Research Institute of observational sciences	India
Yogesh Wadadekar	National Centre for Radio Astrophysics	India
Liu Jifeng	National Astronomical Observatories, CAS	China
Chenzhou Cui	National Astronomical Observatories, CAS	China
Russ Taylor	Inter-University Institute for Data Intensive Astronomy	South Africa

+ 108 co-investigators from all 5 BRICS countries

- Investigating the transient and variable Universe
- Preparing for the Big Surveys to come

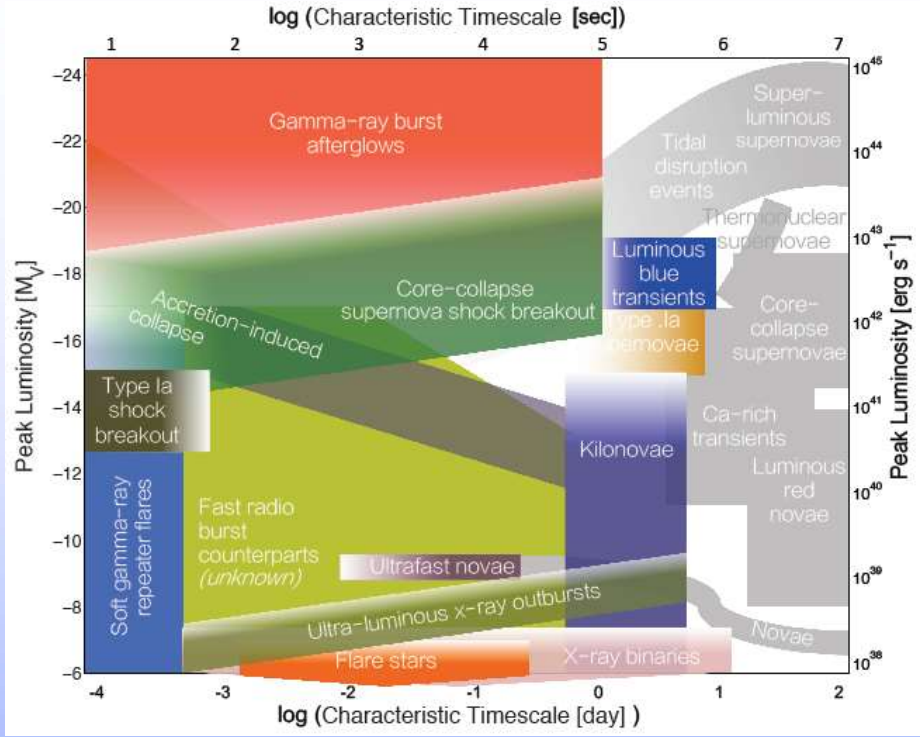
Science Drivers: The Transient Universe

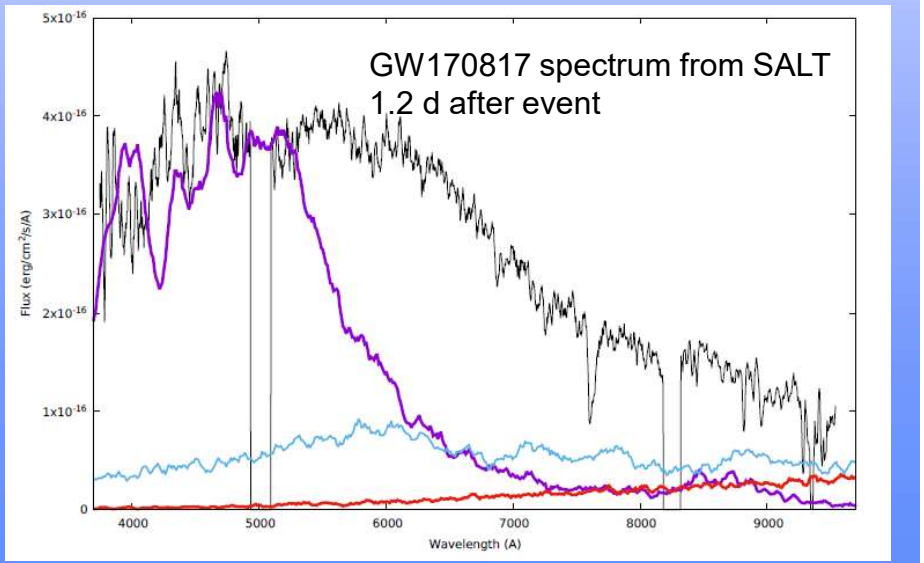
- Time domain and transient astronomy is new frontier of discovery space
  - "things that go bump in the night"
- Allows studies of variability over timescales of milliseconds to years
- Observations of transient behaviour for a wide range of objects and timescales
  - From the closest (Solar System) to the furthest
  - Some of the most energetic objects in the Universe
  - Opening the frontiers of time domain multi-messenger astronomy



Transient Science

- **Building on experience with transient programmes in BRICS (e.g. with SALT)**
- **Covering wide range in luminosity (& distance)**
- **Variability on wide range of timescales**
  - **Fast transients (subsec – day) a new frontier**
- **Covering many object classes**
  - **X-ray transients**
  - **Cataclysmic Variables**
  - **Novae**
  - **Intermediate luminosity transients**
  - **Tidal Disruption Events (TDEs)**
    - » **From Gaia, OGLE, eROSITA**
  - **Black Hole microlensing events**
  - **Flaring Blazars**
  - **Changing-look AGN**
  - **Unusual supernovae (e.g. Super Luminous, fast)**
  - **Gamma-Ray Bursts (GRBs)**
  - **Radio transients with MeerKAT**
  - ***Multi-messenger (e.g. Gravitational Wave events (subject of 2022 STI prop)***





First Phase: Develop an Intelligent Observatory Network utilizing BRICS existing facilities

Leverage SAAO's initiative to make the whole Sutherland site an integrated intelligent machine for transient and survey follow-up

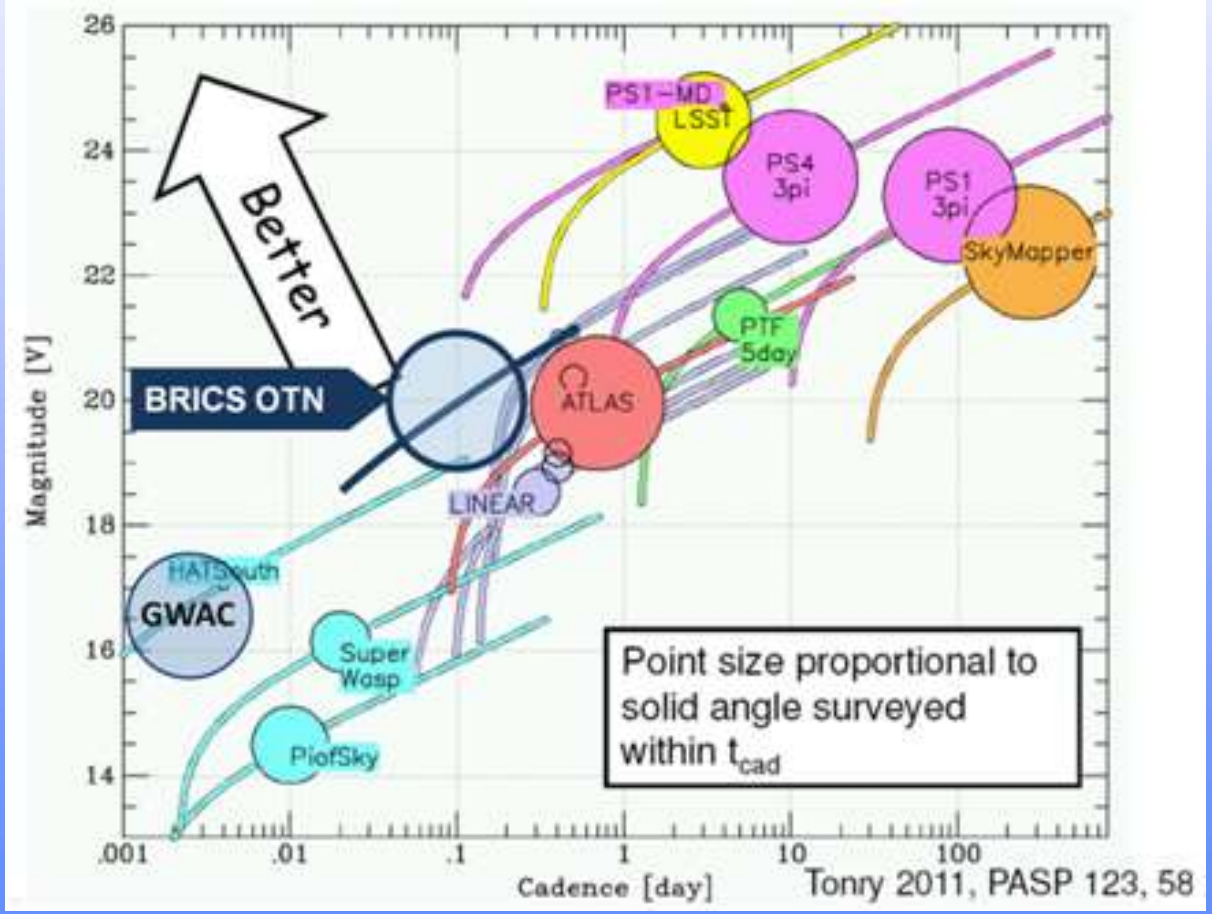
This work began in 2020:

- resources being providing development of SW target selection and scheduling tools for automated follow-up of transient alerts (in collaboration with other groups (e.g. LCO)
- Synergy with South African participation in LSST
- Potential to involve ~11 telescopes

Future Developments of the BRICS Intelligent Telescope and Data Network

Second Phase: Development of a global network of *new* 1-m class telescopes

New discovery space:



BRICS Intelligent Telescope and Data Network

Second Phase: Development of a network of *new* 1-m class telescopes

Top Level Requirements:

- A survey rate of >5000 deg^2/ hr to achieve an ultimate aim for ~1 h cadence *over the entire sky* (unique).
- Distributed in latitude & longitude, including (but not limited) within BRICS countries (e.g. Chile, Australia, La Palma as additional sites)
- 24h operation time. This requirement is important to ensure that the system will be able to respond to any alert and any given time on night sky.
- Limiting magnitude of at least AB ~ 21
- *g, r, i* filters (dedicated to specific telescopes)
- Fast readout cameras (also use for high time resolution photometry
- Angular resolution better that 2 arcsec is required (ideally match to seeing)
- *Will open new frontier on time domain astronomy potentially discovering fast and rare transients impossible to detect with more limited cadence surveys*

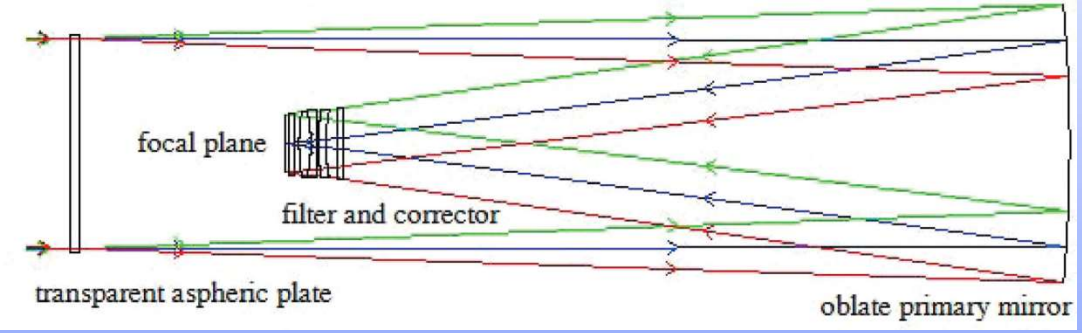
Start with building of proto-types to test performance. Eventually install groups of 3 telescopes at different sites.

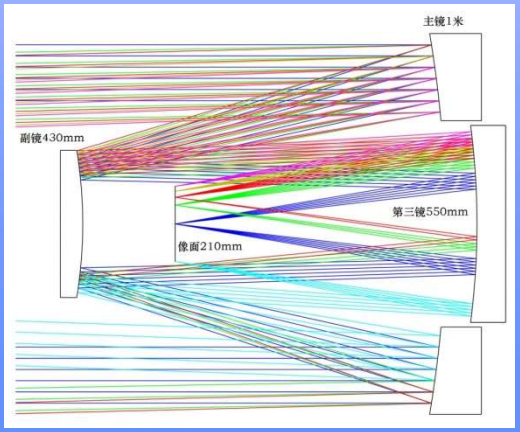
BRICS Intelligent Telescope Network

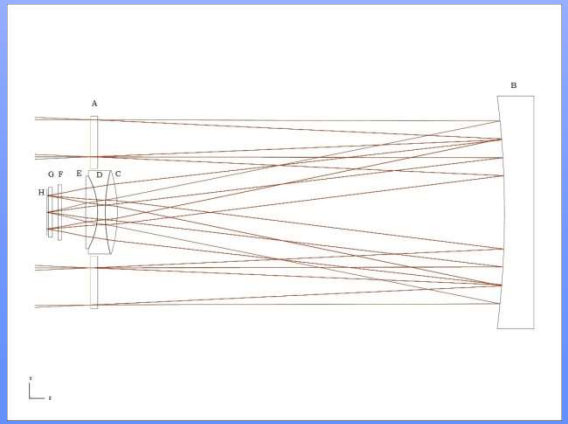
Second Phase: Development of a network of *new* 1-m class telescopes

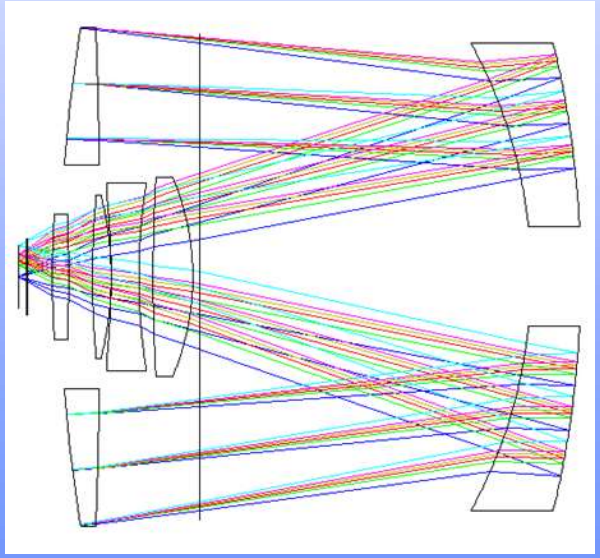
Telescope design:

- Already initial design work done as part of Chinese (*Sitian; Liu et al.*) and Russian (*PHOBOS; Shustov et al*.) studies
- These will be taken forward in an initial design trade-off study







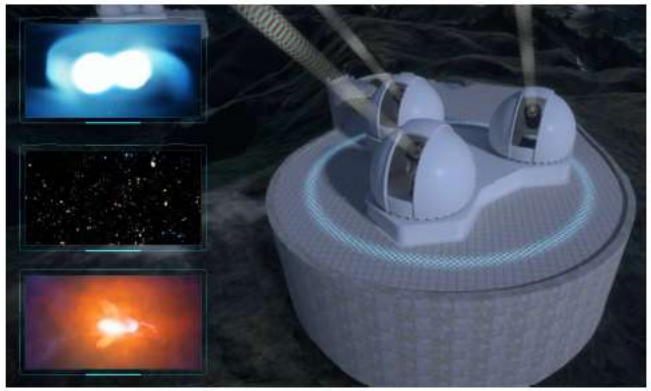


Proposed Chinese and Russian (right; modified Hamilton designs

Chinese Developments

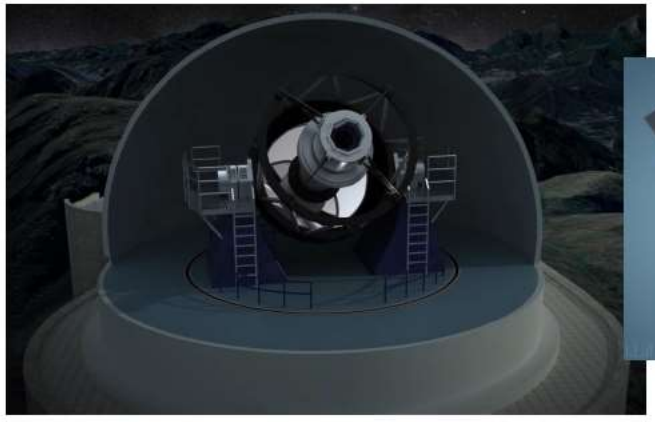
- ***Sitian* concept**
  - **~70x 1-m wide field telescopes**
  - **2 -3x 4-m follow-up spectroscopic telescopes**

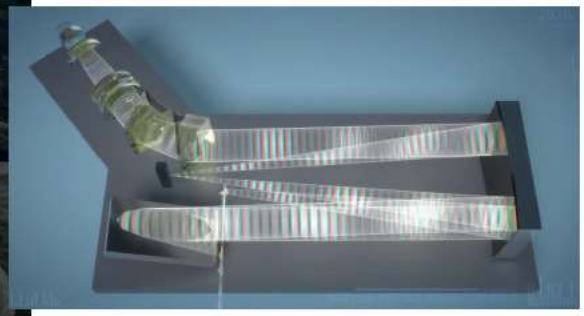
➢ Fast\ Wide\ Deeper ARRAY



➢ Global\ Multi-band ARRAY

➢ 4m Following SPECTROGRAPH





- 0.5 hr Sampling
- 10 Thousands square degrees
- 21mag limited

Chinese Developments

- ***Sitian* progress**

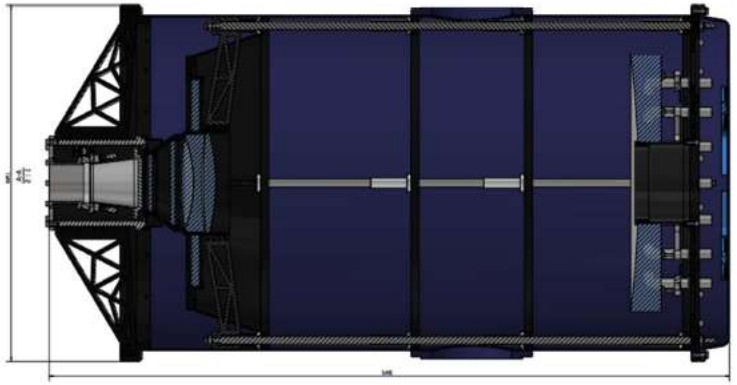
☐ Updates of Sitian Prototype

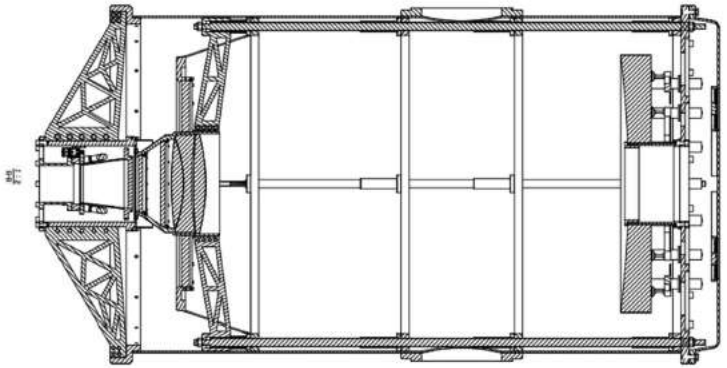
- ➢ Optical elements manufacturing
- ➢ Equatorial Mount assembling
- ➢ Estimated in-situ deploy (Dec, 2022)

◆ Equatorial Mount of Sitian (2022)

◆ Primary and Aspheric plate

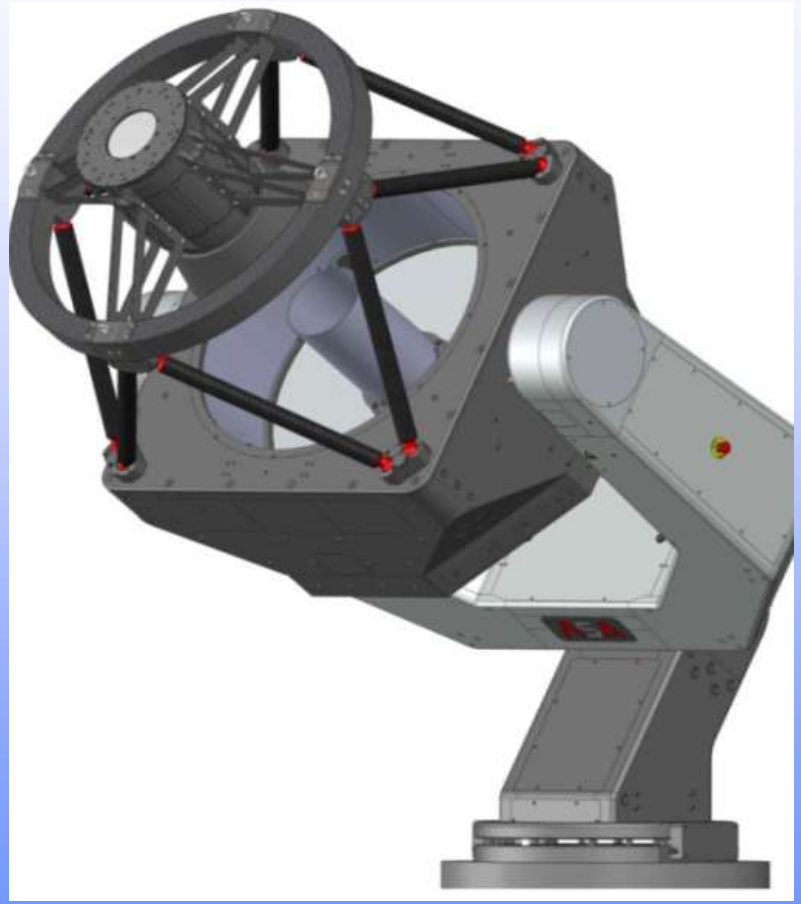
◆ OTA manufacturing

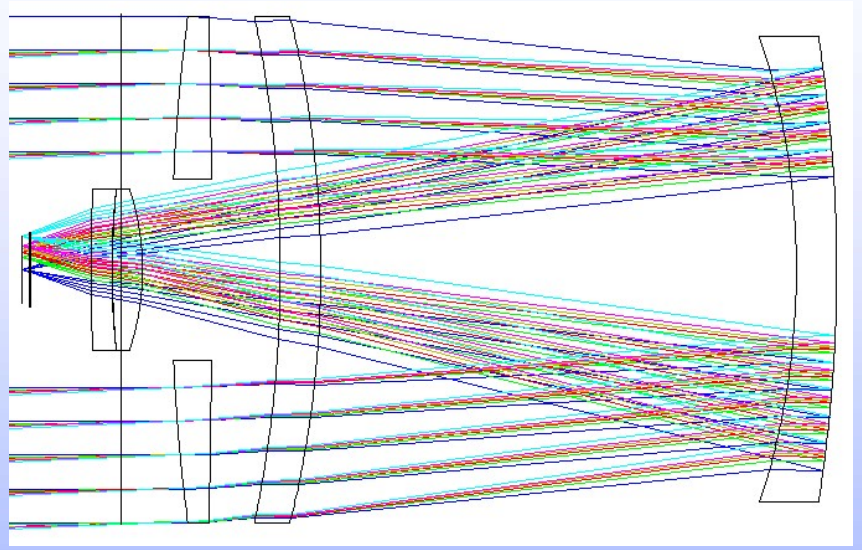




Russian Developments

- *INASAN* (Institute of Astronomy RAS) concept
  - ASA 1.0 m wide field telescope; 10-20 sq deg FoV
  - 90 mm CMOS detector





Sonnefeld design (Shmagin, INASAN)

Summary of BITDN Flagship benefits to BRICS

- Promotes collaboration and development amongst BRICS countries and their existing partners in science and engineering
- Large potential for human capacity development
- Focuses on the enormous scientific potential of multi-wavelength studies of astronomical transients and followup from surveys, for decades to come
- Will be ideal tool for supporting multi-messenger astronomy, e.g. E-M counterparts of GW events (this is the subject of a 2022 proposed 3-year STI project)
- Internationally competitive and unique – a true *flagship*
- Opportunity to collaborate globally
- Utilizes existing and future multi-wavelength facilities (optical, IR, radio, X-ray, γ-ray, UV)
- Impactful on a wide level
- Can start with relatively modest investment and grow as funding allows
- Ticks all the boxes for the criteria of a *flagship program*

Costs/Budget

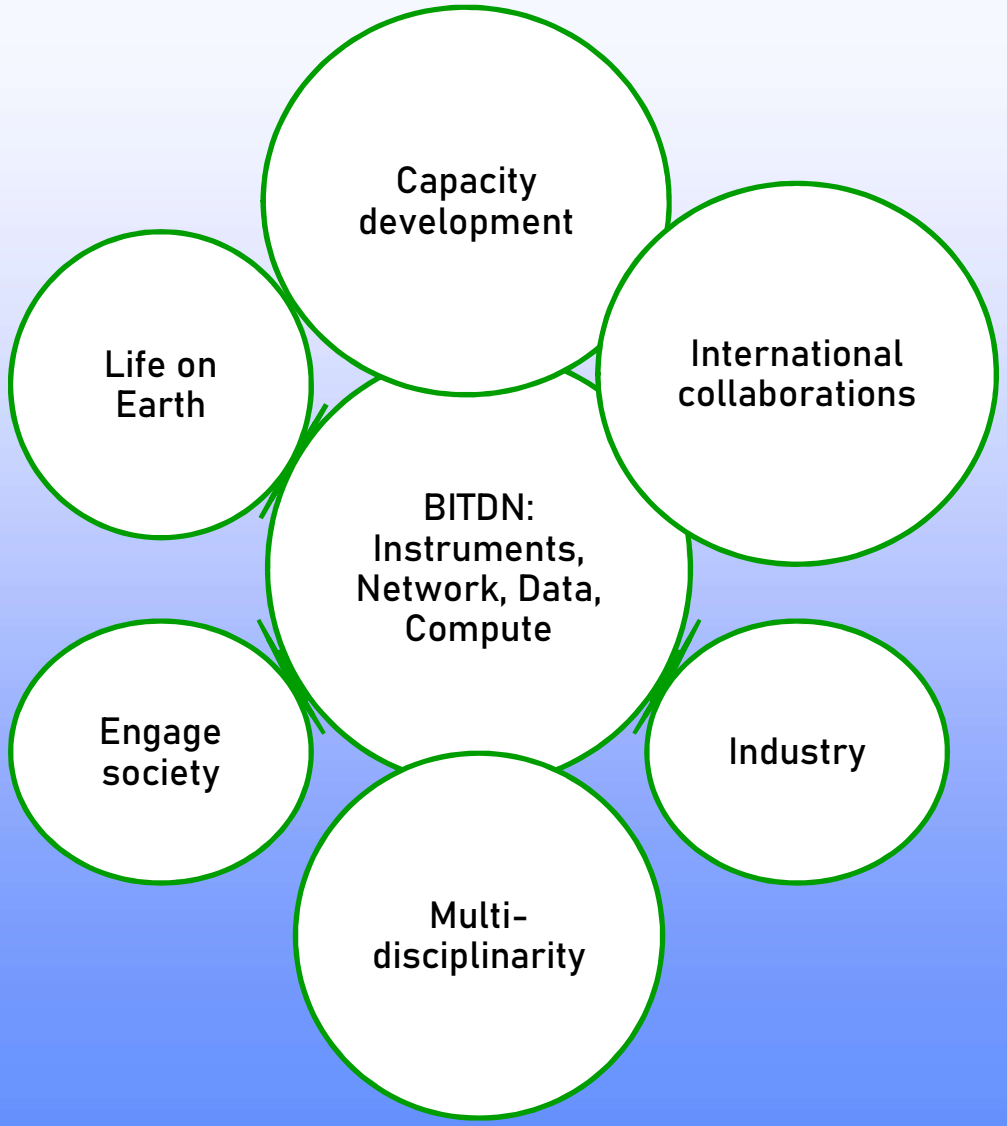
The budget for the BRICS Intelligent Telescope and Data Network (BRICS-ITDN), over the proposed 9 years of the programme (2021-2029) consists of funds to support the following:

- BRICS-OTN annual project meeting.
- Travel for joint technical work, research collaboration meetings and workshops
- BRICS post-doctoral (12) and post-graduate (12) fellowships.
- Project management and software & systems development.
- Outreach and Astronomy for Development activities, including a Co-ordinator
- Equipment and Infrastructure
- SALT and other large telescope access costs
- Costs for 4 prototype new wide-field 1-m telescopes
- Cost estimate of ~$30M over ~9 yeara
- Seed funding committed from SA in 2021, including for 3 positions (R9M)
- Expectation of other countries to begin co-funding soon

Societal Benefits

- **Science goals are:**
  - **Transients & variables & time domain astronomy**
  - **Big Data, Big Compute for support of survey science**
- **Societal Benefits projects are a third *equally important* pillar of the program**
- **Large component of HCD**
- **Also tied to the UN Sustainable Development Goals (SDGs)**
  - **Synergies with projects of the IAU OAD**

Societal Benefits



Societal Benefits

Training young scientists and technicians

- Postgraduate scholarships
- Research schools
- Big data workshops and hackathons
- Conference participation
- Virtual hubs

Virtual hubs

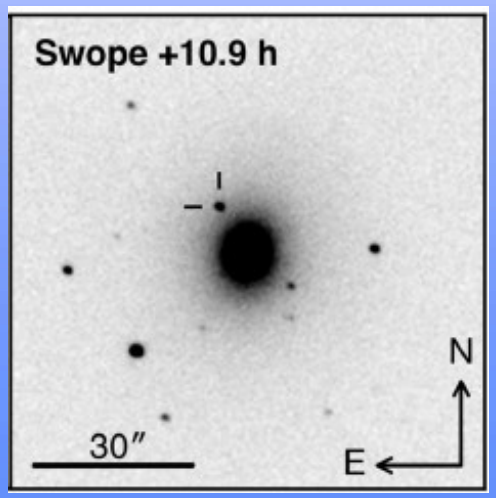
- With industry
- Across languages
- Across timezones
- Diverse learning modes

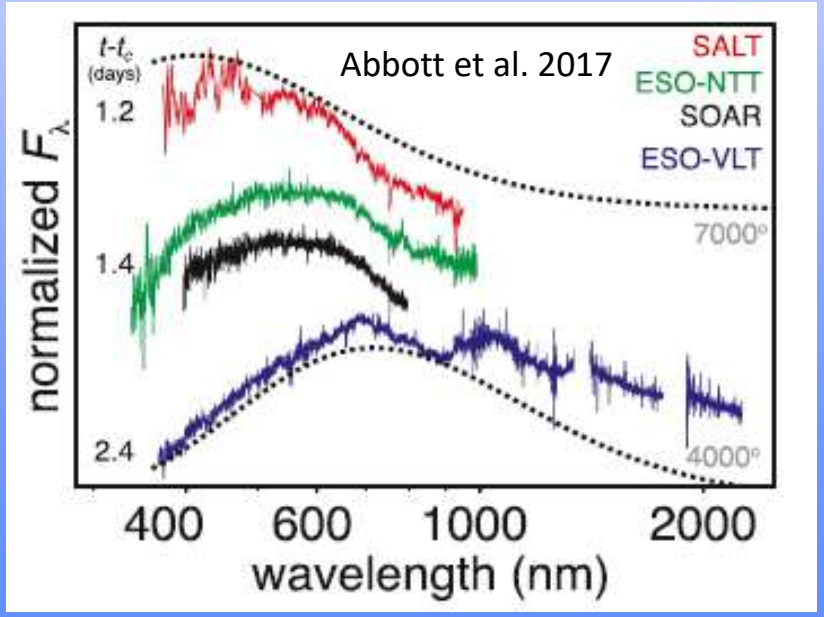
Develop state-of-the-art training & collaboration opportunities for students in the network

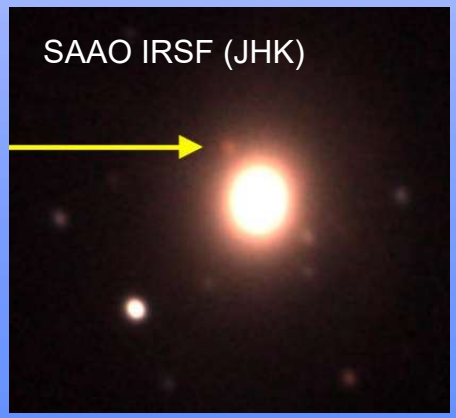
A BRICS 2022 STI Proposal:

Constraining the Nature of Multi-messenger Transients with Coordinated Multi-wavelength Observations

- **Pre-cursor to BITDN Flagship on focused theme with 3y timescale**
- **Leveraging potential discoveries of optical counterparts of Gravitation Wave source from the O4 LIGO/VIRGO/KAGRA campaign (beginning ~March 2023)**
- **Harnessing all BRICS observational facilities**
- **Example of forefront science: 2017 detection of a kilonova counterpart of first EM source of GW emission from a binary neutron star merger (GW170817) located in nearby galaxy NGC4993**







The End