BRICS Astronomy Proposals for Collaborations

Submitted Ideas For BRICS Astronomy (6 proposals from China)

2018 BRICS ASTRONOMY WORKSHOP & WORKING GROUP MEETING

Ideas for strengthening BRICS astronomy into the future

29-31 October 2018

PROTEA HOTEL, UMHLANGA ROCKS, DURBAN, South Africa

Outline

1. Radio Astronomy, Geodesy and Space Science (#10)
2. FAST and MeerKAT (#13)
3. Big Data towards the SKA (#14)
4. 21cm Cosmology (#15)
5. Sitian Project (#16)
6. High performance computational astrophysics & multi-wavelength observational astronomy (#17)

South African-Chinese Collaborations in Astronomy （2015 March 16-18）

7 topics: Radio Astronomy(6)、Optical and infra-red Astronomy(4)、γ- andX-ray Astronomy(2)、Computational astrophysics(4)、Virtual Observatory(2)、Human Capacity Development and Education(4)、Science Engagement and Public Outreach(4)

Basic Information

No	PIs in China	Partners in BRICS countries
1	Zhiqiang SHEN (zshen@shao.ac.cn) Fengchun SHU Zhongping ZHANG Jinsong PING	1) Roelf Botha, SARAO, South Africa 2) Aletha de Witt, SARAO, South Africa 3) Dmitry Marshalov, Institute of Applied Astronomy of RAS, Russia 4) Alexey Melnikov, Institute of Applied Astronomy of RAS, Russia 5) Alexander Kosov, Institute of Space Sciences of RAS, Russia 6) Alexander Gusev, Kazan Federal University, Russia
2	Bo PENG (pb@bao.ac.cn)	1) Claude Carignan, University of Cape Town, South Africa 2) Yashwant Gupta, GMRT, Tata Institute of Fundamental Research, India
3	Chenzhou CUI (ccz@bao.ac.cn)	1) Russ Taylor, University of Cape Town, South Africa 2) Yogesh Wadadekar, National Centre for Radio Astrophysics, India
4	Xuelei CHEN (xuelei@bao.ac.cn)	1) Yinzhe Ma, University of Kuazulu-Natal South Africa 2) Tirthankar Roy Choudhury, Tata Institute for Fundamental Research 3) Elcio Abdalla, University of Sao Paulo, Brazil
5	Jifeng LIU (jfliu@bao.ac.cn)	1) David Buckley, SAAO, South Africa 2) Renato Dupke, National Observatory of Rio De Janeiro, Brazil
6	Rainer SPURZEM (spurzem@bao.ac.cn)	1) Stephen Potter, SAAO, South Africa 2) Dmitry V. Bisikalo, INASAN, Russia 3) Dipankar Bhattacharya, IUCAA, India

VLBI for astrometry and geodesy

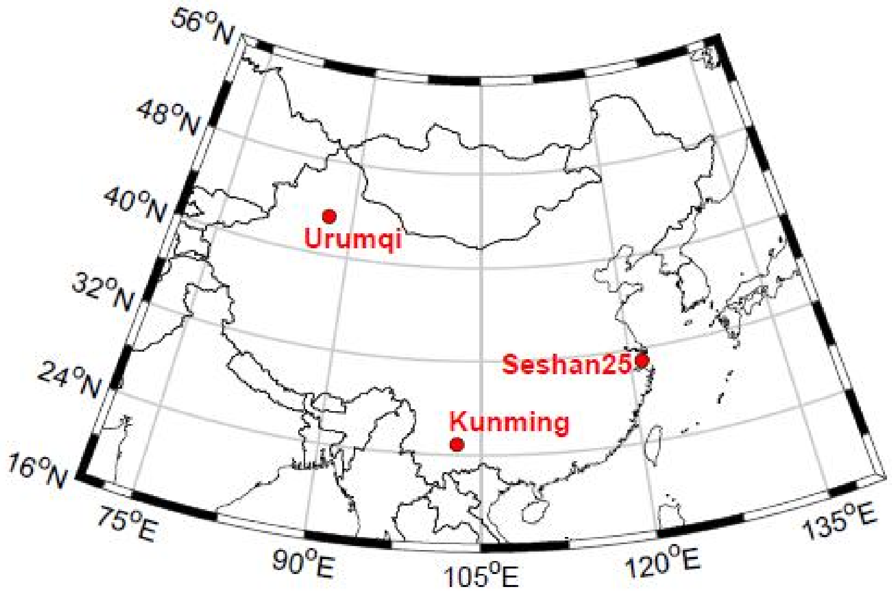
- VLBI Ecliptic Plane Survey (VEPS)
  - To search for new ecliptic plane sources and improve their positions accuracy
  - to observe 450 ecliptic sources (declination>-10°, correlated flux density>60mJy) by using QUASAR+CVN network
  - To observe other sources by using VLBA/EVN/AOV
- VLBI SOuthern Astrometry Project (SOAP)
  - to improve positions of all known VLBI sources at declinations < −30° to 0.3mas level
  - a proposal to the IVS to become an operational center for southern astrometry
- K-band Astrometry
- VGOS development
  - New VGOS antennas in China, Russia and South Africa
  - Correlator operation in the VGOS era
  - Joint observations and data processing for EOP and ITRF determination

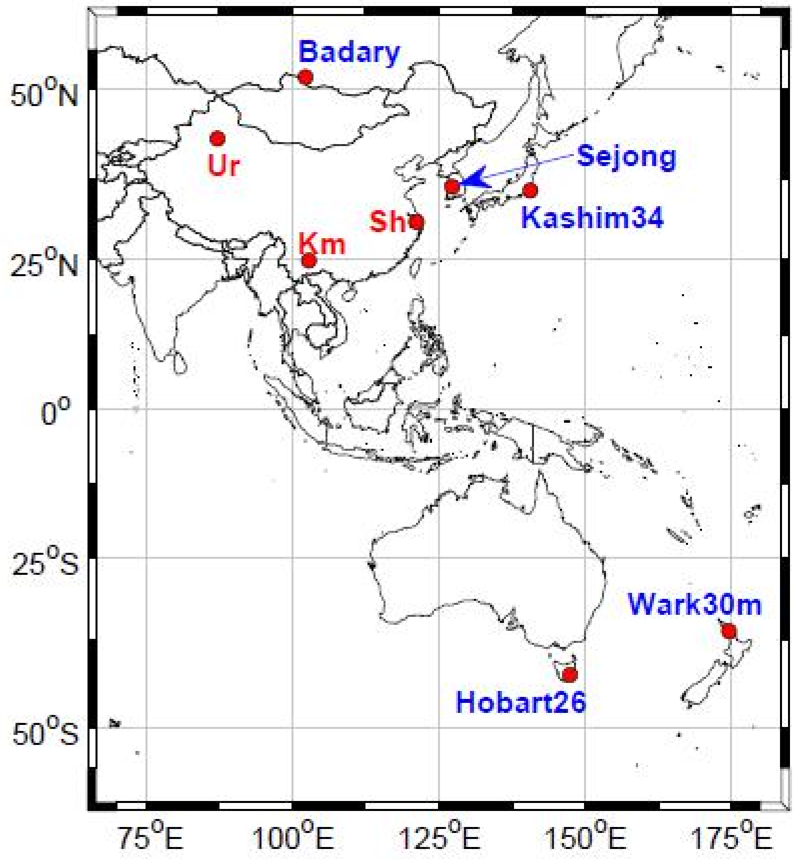
Ranging observations to satellites and the moon

- To conduct coordinated SLR observations to specific satellites, and LLR observations to the moon.
- To conduct radio ranging observations to the Chang'E lunar landers and study the dynamics of the Moon and the Earth.
- To conduct radar observations and study the physical properties of the Moon.
- To cooperation on the SLR/LLR technique development.

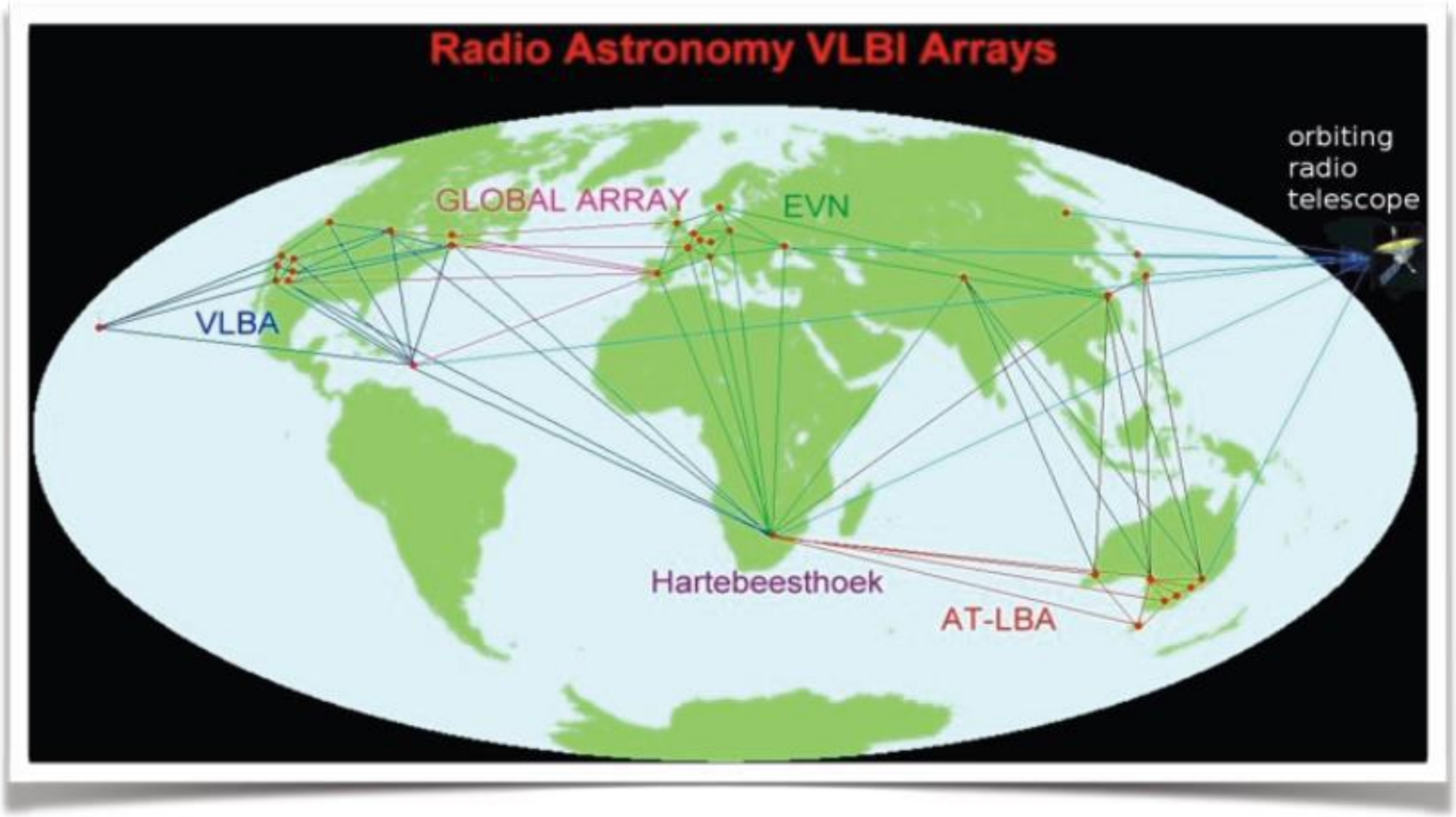
Search for new ecliptic plane sources

- Core stations
  - Sh, Km, Ur
- Cooperation stations
  - Kv, Kb, Ho, Wa, Bd



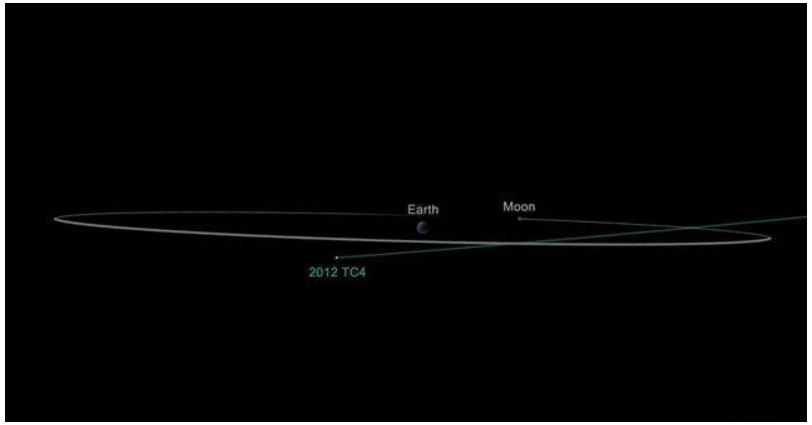


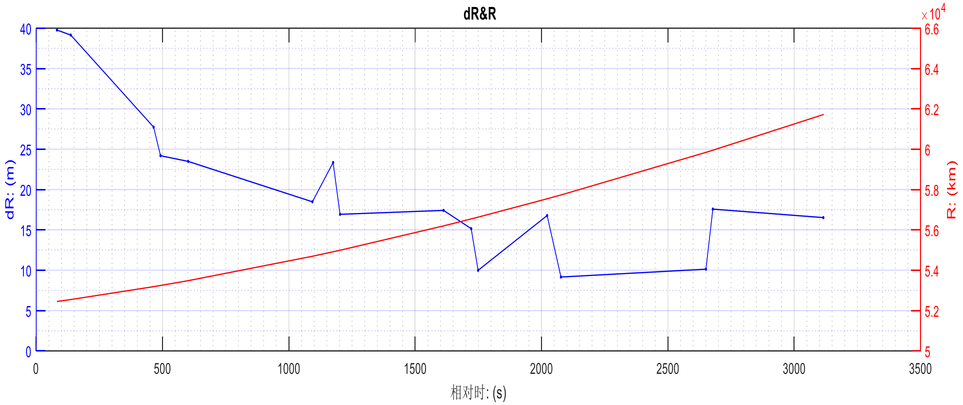
"Filling the gap" with the AVN

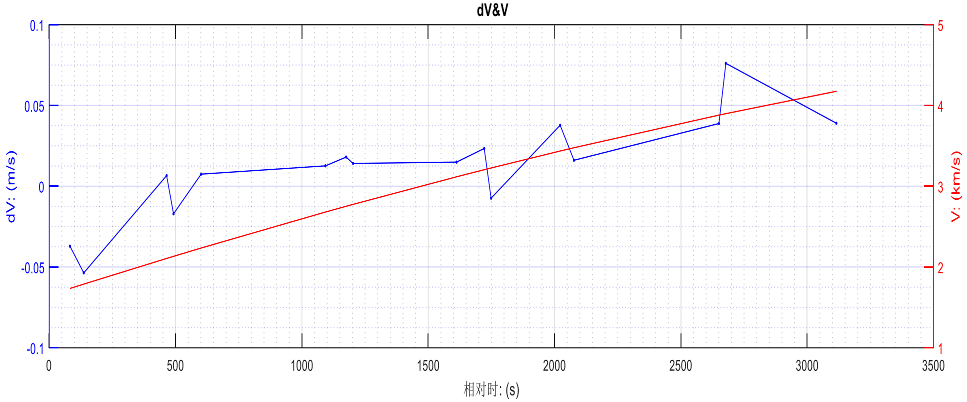


Testing radar observations and preliminary results

- Pulse echo from the asteriod 2012 TC4 received at the station







Predicted values of 2012 TC4 radial distance and radial velocity based on the ephemeris published by NASA JPL and its residual curves compared with radar measurements.

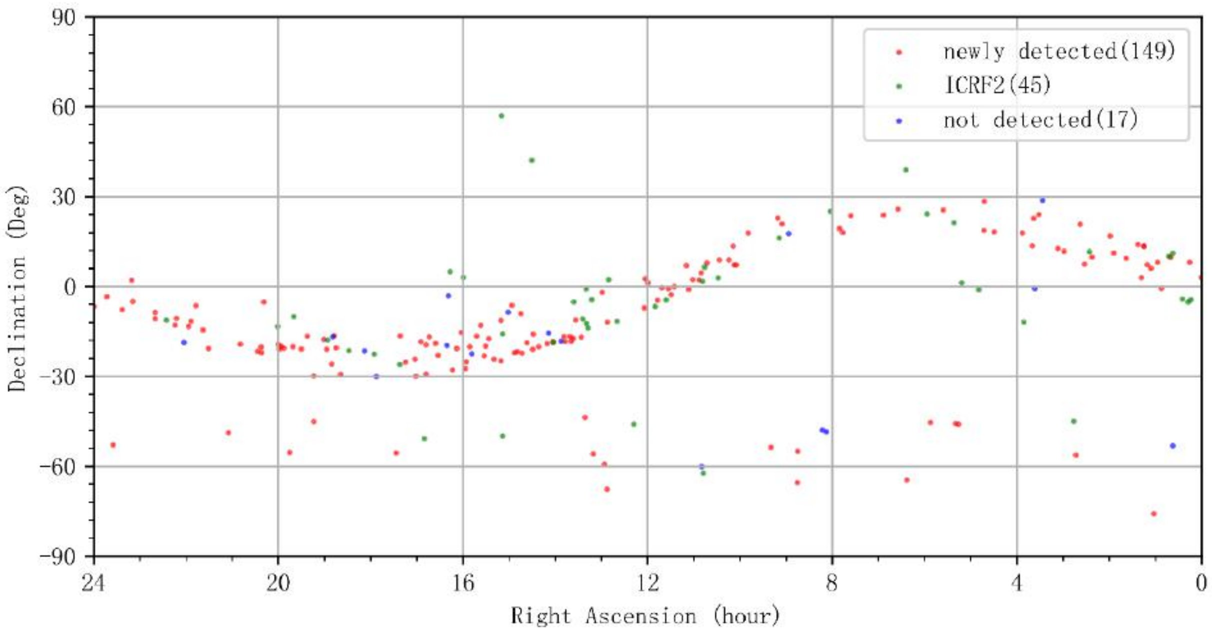
Prospect of radar astronomy research

- Update the radar facility
  - Using H-maser clock, in replace of oscillator
- Update the radio antennas
  - Installing a new recording system
- Construction of new receiving radio antenna
- Construction of new transmitting radar antenna

Absolute astrometry of weak (ecliptic) sources

- VLBA
  - BS250: 4*8h, 110 target sources
  - BS264: 6*8h, 124 target sources
- EVN
  - ES087(T6+Ef): 24h, 115 sources
  - Thanks Alet for preparing proposal
- AOV
  - AOV
  - APSG

Contribution to the ICRF3



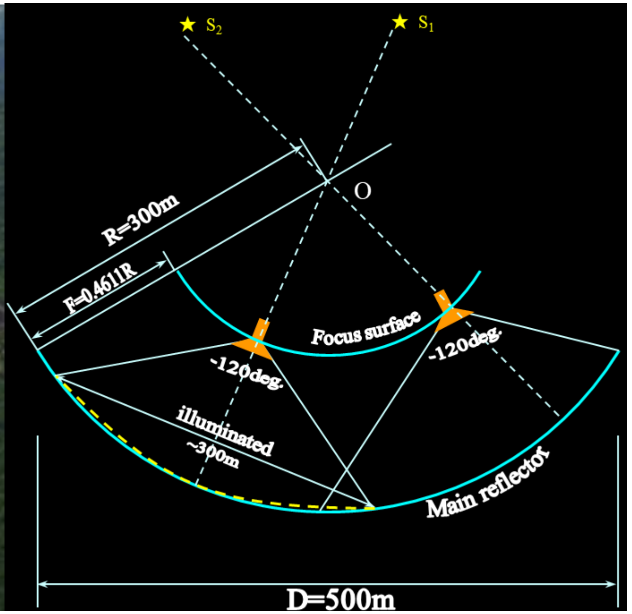
- Compared with ICRF2, the ICRF3 has 1122 new sources. Among them, 149 sources (13.3%) have been observed by AOV sessions, and 132 sources were firstly observed in the AOV.

2 science cooperation between FAST & MeerKAT

1. **Aim**
2. **Timeline**
3. **BRICS partners:**

   South Africa, China, India

4. **Resources required**



1. Aim

- to strengthen the science cooperation between the largest single dish telescope, **FAST**, and the largest aperture synthesis array telescope, **MeerKAT**.
- to study:
  - new pulsars and some exotic events
  - HI gas in nearby galaxies
  - low-frequency gravitational waves (GW) using the high precision pulsar timing
  - massive black holes
  - interacting galaxies in galaxy pairs and in groups of galaxies

2. Timeline

- Short term (1-3 yrs)
  - To discuss future scientific collaborations and foster Key Science Projects (KSPs) among scientists in BRICS partners.
  - To train the next generation of scientists for research with SKA1.
  - To build better personal relationship between pulsar researchers in both countries.
- Medium term (3-5yrs)
  - To make long-term surveys for KSPs and PI projects.
  - To do the big data analysis of the observation results generated by FAST and MeerKAT.
- Long-term (over 5yrs)
  - Over 5 years, the science teams fostered from the cooperation of FAST and MeerKAT will be involved in the first observations of SKA1, and make contributions for great scientific discoveries of SKA1.

3. BRICS partners

- Professor Claude Carignan, University of Cape Town South Africa
- Professor Bo Peng, National Astronomical Observatories, CAS (NAOC) China
- Professor Yashwant Gupta, Giant Metrewave Radio Telescope, Tata Institute of Fundamental Research, India

4. Resources required

- Some resources are required, namely
  - expenses for academic exchanges
  - data center for archive of the observational results of the telescopes and related development of science analysis tools.

  - Cost in 5 years about €360k Euro,
    - about €100k Euro is for the exchanges (€5k/person/year*4 persons*5years)
    - about €260k Euro is for a 2PB data center (~€0.13/GB*2PB)

- The CAS Key Lab of FAST is involved in this project, and will provide related facilities and human resources.

3 Big Data Research Infrastructure Collaboration towards the SKA

Prof. Chenzhou Cui

National Astronomical Observatories, CAS

Description of the proposed project

- Leading Institute
  - South Africa
- Partners
  - China
  - India
  - Brazil

Prof. Russ Taylor

University of Cape Town, South Africa

Dr. Yogesh Wadadekar

NCRA, India

Dr. Luiz White

Brazil

- Astronomy is one of several research fields currently facing an era of mega-data.

- This proposal brings together research and development teams at major institutions in four BRICS partners to collaborate on the development of Information Technologies and HPC solutions to address big data processing and analytics in astronomy, on the pathway to the SKA.

Overarching requirements in the data intensive research era

- To empower individual researchers and research teams to work with big data,
- To enable collaborative research among globally distributed researcher (the new paradigm for research into issues of global import),
- To provide training and transformation to grow a cohort of young South African researchers, technologists and data scientists.

3 Big Data Research Infrastructure Collaboration towards the SKA

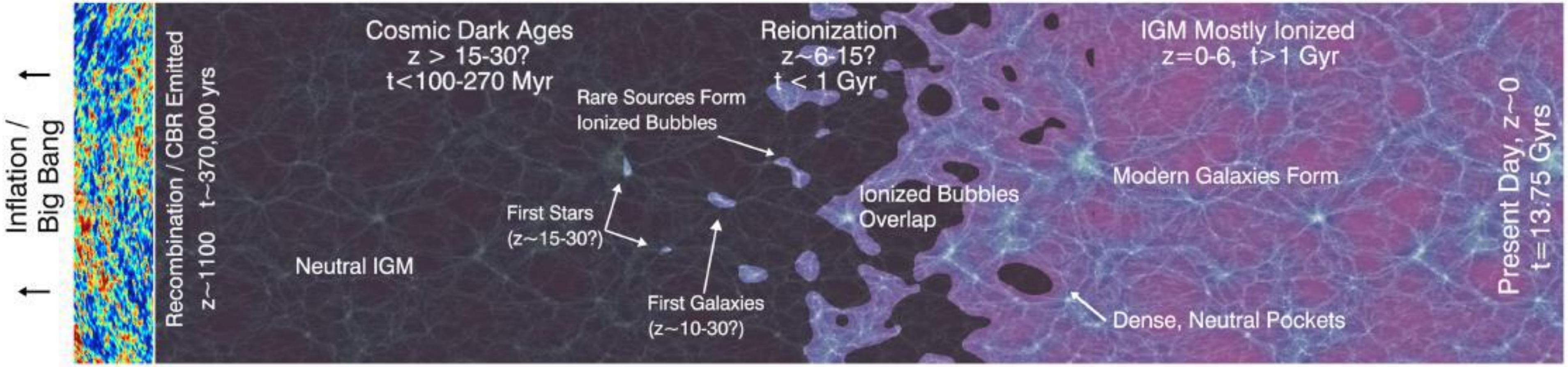
Project Major Contents

- development of methods in open source cloud implementation and technologies,
- development of novel algorithms and HPC software for processing and analysis of big astronomical data,
- Build up open source based architecture and tools to enable deployment of HPC systems, and
- Human Capital Development.

Tangible outputs

1. a network of federated cloud-based infrastructure and e-science tools
2. cloud-based provisioning of HPC for automated processing pipelines
3. a VLBI post-processing data pipeline and source extractor that are both in python script form and available as a Jupiter notebook new technologies and modalities for visualization, such as machine learning enhanced visual analytics of cloud-based remote big data,
4. a visual classification tool improving upon the past experience of Radio Galaxy Zoo to allow astronomers and citizen scientists to easily browse, classify and annotate ‘peculiar’ radio sources and thus help to discover the unexpected by fully leveraging the power of multi-wavelength data.
5. cloud-enabled systems for fusion and analytics of LSST and radio data
6. innovative data analytic tools for large datasets, driven by machine learning techniques
7. cloud-based tools for collaborative exploration by distributed research teams
8. a cloud-based astronomy & data science toolkit

4 21cm Cosmology

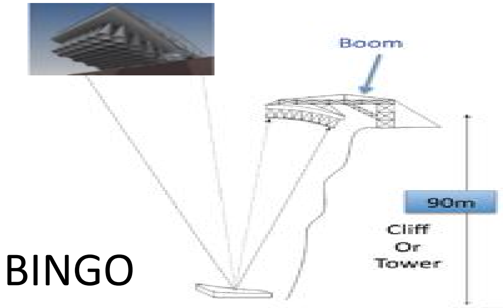


- neutral hydrogen (HI) 21cm radiation provides a ubiquitous probe for cosmology

- So far the detection is very limited, but have great potentials and at the forefront of research

- BRICS member countries have a very strong foundation on 21cm cosmology research, more than half of the existing experiments in the world are located in BRICS member countries!

Some BRICS experiments



Collaboration Ideas

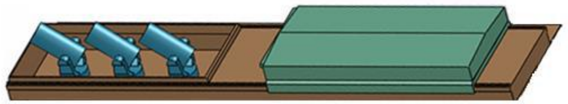
- 5 year research

- Initially meeting, joint research, exchange data, people, eventually joint facillities

- PIs:

  Xuelei Chen/NAOC/China
  Yinzhe Ma/UKZN/South Africa
  Tirthankar Roy Choudhury/ Tata Institute for Fundamental Research/ India
  Elcio Abdalla/University of Sao Paulo/Brazil

5 Sitian Project



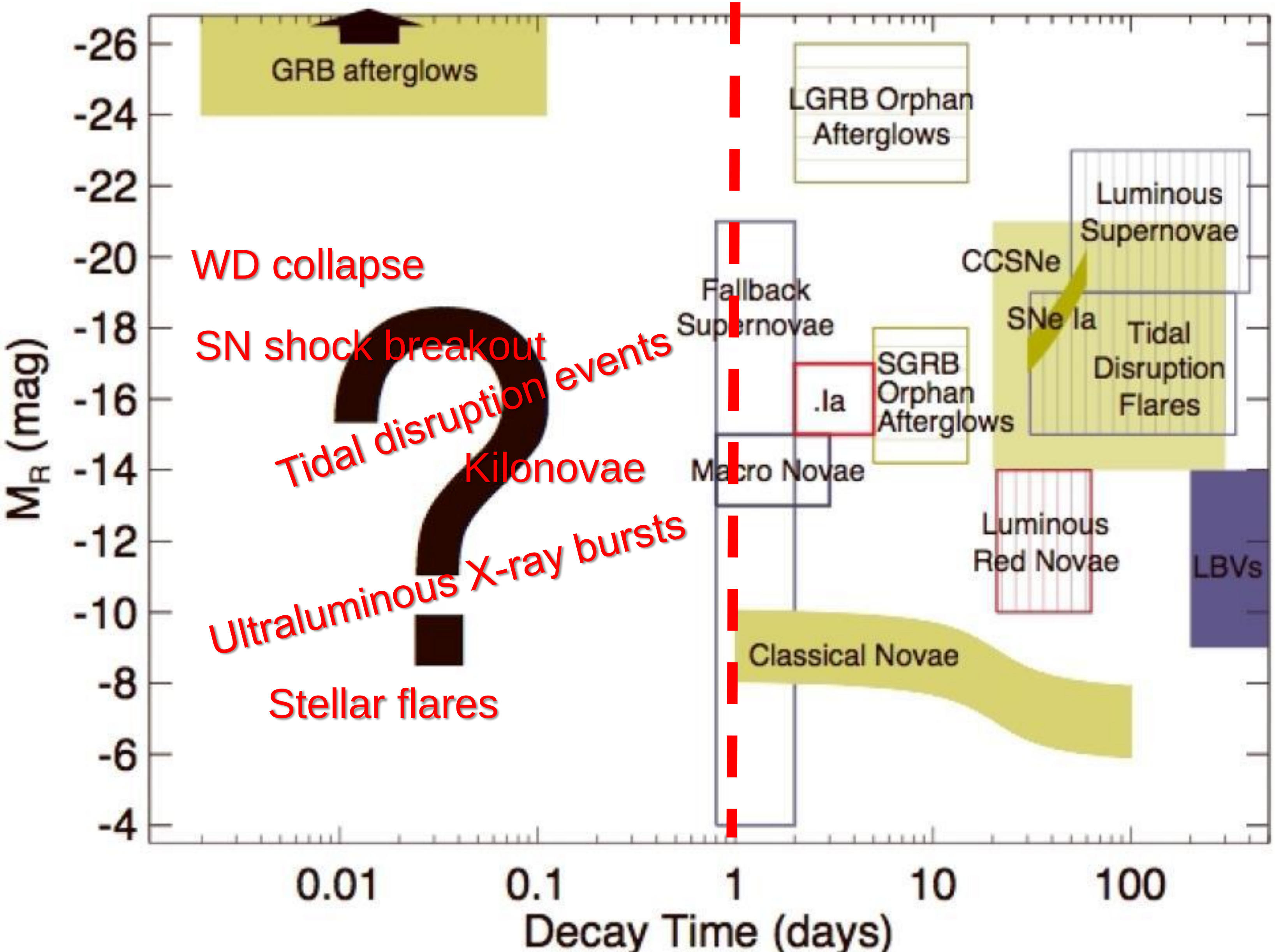
Sitian (司天) project

A new world-wide network of telescopes to explore the fast-variable optical sky

Project Chief: Prof Liu Jifeng
National Astronomical Observatory
of the Chinese Academy of Sciences

Sitian Project

Fast-variable optical sky still mostly unexplored



5 Sitian Project

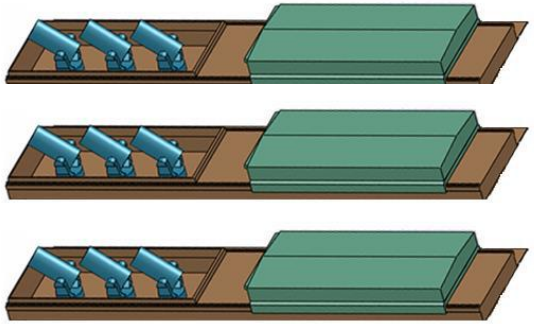
Sitian = system of optical telescopes
to explore new regions of time domain

- All-sky monitoring (North and South)
- 1-m telescopes installed world-wide
- Full scan of the sky every 30 min
- Simultaneous 3-color images (*g*,*r*,*i*)
- 21.5 mag reached in each scan
- Spectroscopic follow-up with 4-m telescopes

Sitian-I: 72 1-m telescopes, w/ 60 in China
Sitian-II: 72 + more telescopes, in Chile and worldwide

Sitian project = telescopes network + computing brain

Sitian-I network:

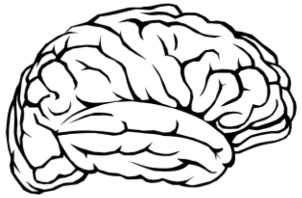


24 units of three 1-m mirrors (*g*,*r*,*i*)
Schmidt optics, 5 deg x 5 deg FOV
Fully automated, 60-sec exposures

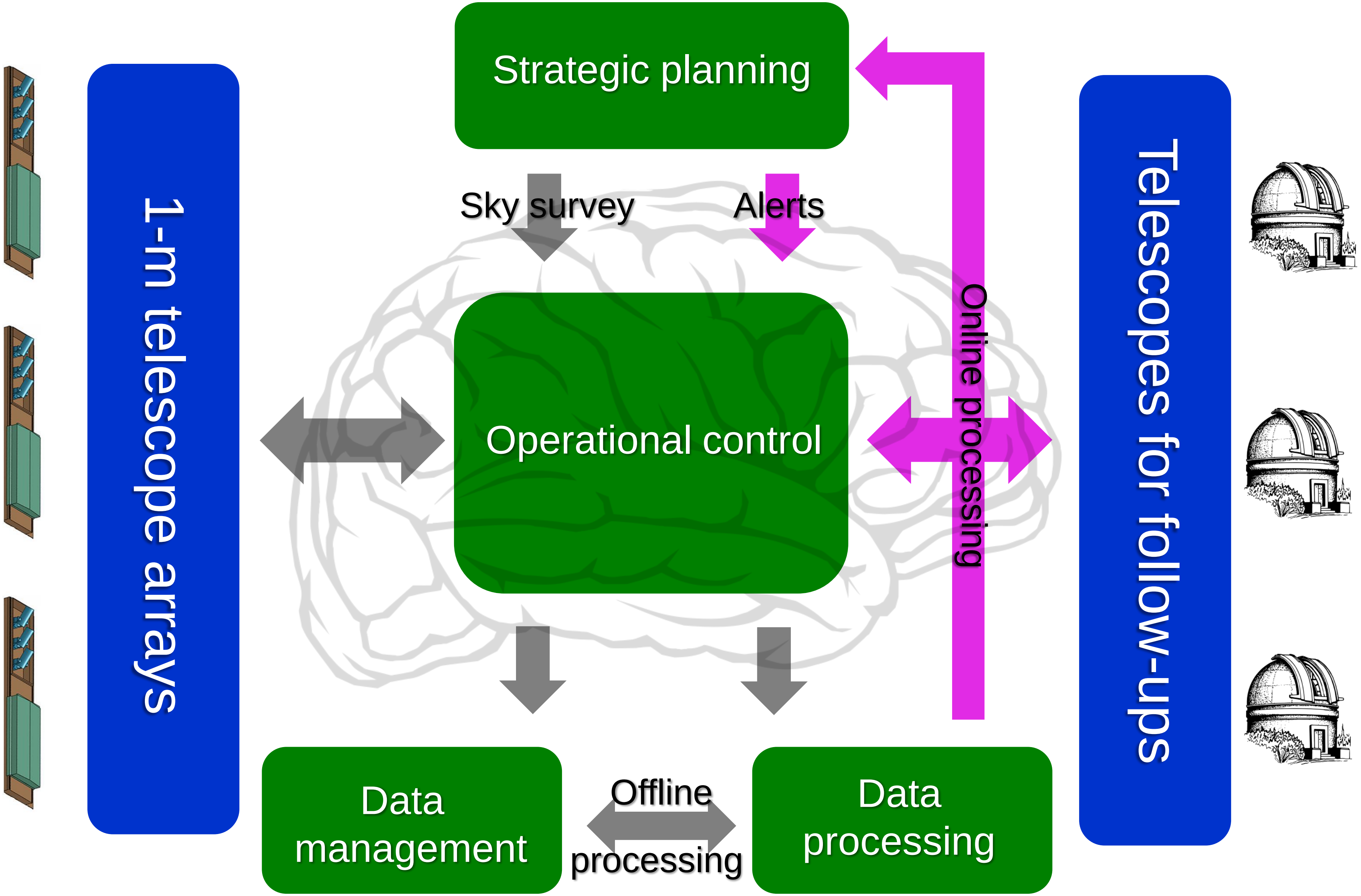
Three 4-m telescopes
for spectroscopic follow-up

Sitian brain:

Operation planning and control of each unit
Data processing and management
Decisions on fast alerts and follow-ups



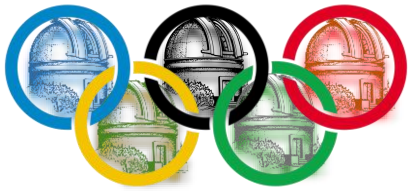
Sitian working mode



5 Sitian Project

Faster/deeper/wider than other optical surveys

Project	Aperture (cm)	Number of 'scopes	Detection limit: Single scan	Detection limit: Stacked	FOV single exposure (sq deg)	Sky coverage (sq deg)	Cadence	Site	Year
LSST	840	1	24.8	27.7	9.6	20000	1 week	Chile	2022-
Mephisto	160	1	--	24.8	3.14	26000	>1 day	China	2021-
Pan-STARRS	180	2	22.8	24.5	7.0	30000	1 week	Hawaii	2010-
Skymapper	135	1	17.7	22.6	5.2	20000	1 week	Australia	2014-
WFST	250	1	--	25.1	6.55	20000	>1 day	China	2020-
ZTF	122	1	20.5	24.3	47.0	30000	2 days	USA	2017-
Sitian-I	100	72	21.5	26.7	**600**	30000	**30 min**	China +global	2021-
	400	3	26.0	--	--	--	--		



Citius, Altius, Latius

5 Sitian Project

Planned world-wide location of Sitian units

Summary of main science objectives

- Optical counterparts of GW events
- Tidal disruption events (TDE)
- Gamma-ray bursts (GRB)
- Fast radio bursts and fast X-ray bursts (FRB)
- Early evolution of supernovae
- Accretion-induced white dwarf collapse
- AGN and X-ray binary outbursts
- Stellar flares
- Exoplanets
- Near-Earth asteroids

Timeline and budget for Sitian-I

- 2021: overall design layout
- 2022—2024: hardware and software design
- 2024: complete infrastructures, start installation
- 2025: complete installation of all 72 telescopes
- 2027: full scientific operations

- Network of 72 telescopes → US$ 300 M
- Follow-up 4-m telescopes → US$ 100 M
- Sitian brain → US$ 60 M

Contact jfliu@nao.cas.cn to find out more

6 High performance computational astrophysics and multi-wavelength observational astronomy

Acronym: HPCA-MWA.

Keywords: High performance computing – Big Data Management - Simulations – Astrophysics

NAOC 中国科学院国家天文台 NATIONAL ASTRONOMICAL OBSERVATORIES, CAS

the SILK ROAD PROJECT at NAOC 丝绸之路 计划

Shanghai Astronomical Observatory
Chinese Academy of Sciences

NRF National Research Foundation | SAAO South African Astronomical Observatory

ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ БЮДЖЕТНОЕ УЧРЕЖДЕНИЕ НАУКИ
ИНСТИТУТ АСТРОНОМИИ РОССИЙСКОЙ АКАДЕМИИ НАУК

Foreign Cooperation Partners:

- **South African Astronomical Observatory, Cape Town**
- **Institute of Astronomy of Russian Academy of Sciences, Moscow**
- **The Inter-University Centre for Astronomy and Astrophysics, Pune, India**

6 High performance computational astrophysics and multi-wavelength observational astronomy

Existing Basis and Feasibility of Cooperation:

- Open Skies from China to South Africa Cooperation –

Sharing Resources and Building Collaborations in Optical and Infrared Astronomy
Conference Lijiang, Nov/Dec 2017: http://cnsa-jointworkshop.csp.escience.cn/dct/page/1

- BRICS Astrophysics, Cosmology and Gravity Cooperation:

International Conference, Durban, South Africa, October 2018 https://acru.ukzn.ac.za/~brics-acg/

- Russia, South Africa, India cooperation on Astronomy since 2009,

China joins now with high performance computing in astrophysics

- Collaboration China-Russia (NAOC-INASAN) Theoretical Astrophysics

Complementarity of Cooperation:

The resources of the Russian side for this program include:

-Russian Science Data Center for the INTEGRAL project
-Telescopes RTT150 (1.5 m), AZT-33IK (1.6 m), AZT-22 (1.5 m), ZTSh (2.6 m)
-Computer center of the Russian Academy of Sciences

The resources of the South African side for this program include:

-SAAO 1.9 and 1.0m telescopes, SALT 10m telescope
-SHOC, the EM-CCD camera, SALTICAM, the SALT CDD camera
-Data reduction and analysis packages (PySALT with SLOTTOOLS for SALTICAM)
-MeerKAT Radio Astronomy Array (64 dishes x 13.5 m)

The resources of the Indian side for this program include:

-1.04m Sampurnanand Telescope (ST)
-1.3m Devasthal Fast Optical Telescope (DFOT)
Access to the ASTROSAT data

The resources of the Chinese side for this program include:

-The super computer of the Shanghai Astronomical Observatory (SHAO)
-SHAO 65-meter radio telescope, 500 Meter FAST radio telescope, LAMOST, and HXMT
-laohu GPU cluster at NAOC (64 Kepler K20 GPUs equiv. to ca. 100 Tflop/s)
-European Supercomputer access through personal grants

6 High performance computational astrophysics and multi-wavelength observational astronomy

Urgency and Expected Achievements of Cooperation:

- *combine expertise in high performance computational astrophysics (HPCA) and multi-wavelength observational astronomy (MWA), compare multi-wavelength observational data with theoretical computer simulations.*

- *New ground and space based astronomy facilities are currently provide some of the most detailed observations of such phenomena particularly in the time domain and transient science arenas. At the same time, the development of high performance computational hardware and numerous algorithms has been unprecedented.*

- *Two aspects to complete our project goals:*
  (i) coordinated management of observational data. Optical and infrared data will be obtained with South African, Russian, Chinese and Indian ground-based telescopes. In addition the radio observatory, the MeerKAT array begins science operations in 2018. European and US space based observatories such as SWIFT and INTEGRAL etc continue to provide real-time alerts of high-energy events as well as the new Indian ASTROSAT X-ray/UV observatory.
  (ii) observational data will provide parameters necessary to refine the high performance simulations. All four partner countries and teams have specialized expertise in different aspects of HPCA and access to HPC hardware that ranks amongst the highest in the world.

Thanks！