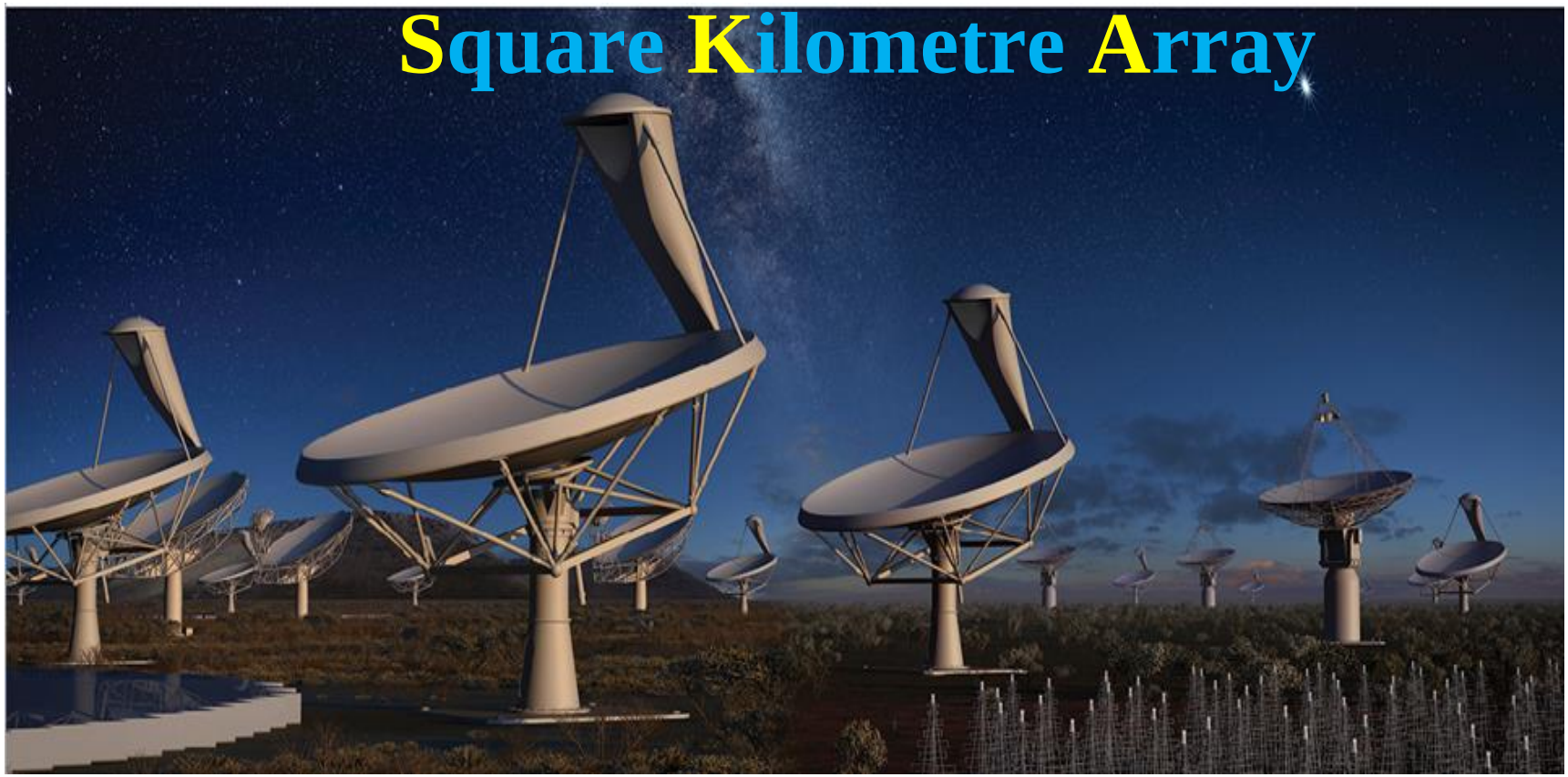
中国科学院国家天文台
NATIONAL ASTRONOMICAL OBSERVATORIES ,CHINESE ACADEMY OF SCIENCES

Long March to the SKA/FAST



Bo Peng @ JLRAT/NAOC

2015 Tianlai Collaboration Meeting and 21cm Cosmology Workshop

Outline

1 SKA Introduction

- Characteristics and Science Drivers
- Rebaseline and Timeline

2 Chinese SKA Participation

- National, Regional, International

3 Chinese Involvement in Pre-Construction Phase

4 FAST Concept and Construction

- Feasibility Studies

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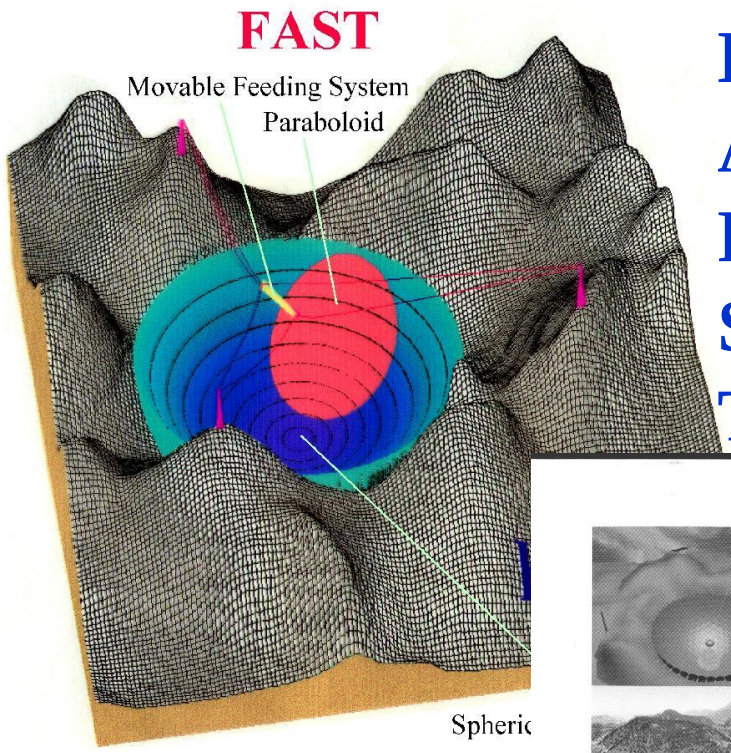
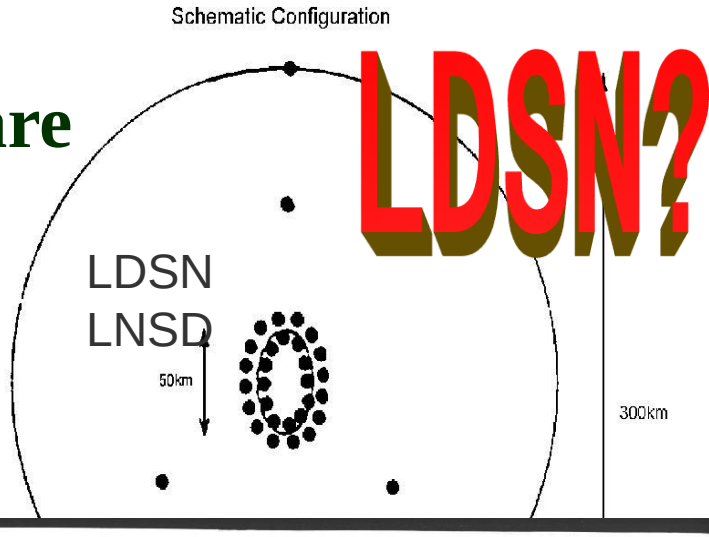
SKA Concepts



Kilometre-square Area Radio Synthesis Telescope



LTWG in 1993

Large Telescope Working Group

ISSC in 2000

International SKA Steering Committee

SSEC in 2008

SKA Science and Engineering Committee

SKA Organization in 2011

Astronomers Sign International Agreement to Plan Square Kilometre Array

Leading astronomers from Europe, North America, Asia and Australia will today sign an agreement jointly to plan a huge new radio telescope, the Square Kilometre Array (SKA), which will come into operation in the middle of the next decade. The General Assembly is an ideal opportunity to inaugurate the next stage of development of this truly global project.

The signing ceremony will take place at 17:30hrs in the Bragg Lecture Theatre in the Schuster Building at the end of the joint session on 'Future Observational Multi-Wavelength capabilities in Astrophysics', organized by the Working Group on Future Large Scale Facilities (WGFLSF) and IAU Division XI (Space and High Energy Astrophysics). The last part of the programme is a round-table discussion on the process of international co-operation and coordination.

Radio astronomers regard the SKA as a paradigm for the organization of future global astronomy projects. The SKA was the first radio astronomy project to have been 'born global' following the guidelines for successful international projects laid down at the 1994 IAU General Assembly in The Hague. The current concept has grown out of discussions over the past six years within the URSI/IAU Large Telescope Working Group and the OECD Global Science Forum. An International SKA Steering Committee (ISSC) has now been

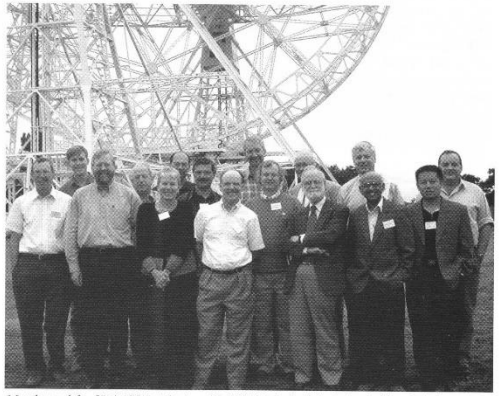
Dr. Jill Tarter: United States SKA Consortium

At present 24 leading institutions in ten countries have agreed to pool their research and development efforts, with each individual institution concentrating on only a part of the overall design. Their shared aim is to reach agreement on the fundamental design of the SKA by 2005 and to begin construction in 2010.

In order to achieve its ambitious astronomical goals, the design of the SKA will integrate computing hardware and software on a massive scale in a revolutionary break from current radio telescope designs. The SKA is a challenging project, and as Ron Ekers of the Australia Telescope National Facility says:

"Designing, let alone building, such an enormous technologically-advanced instrument is beyond the scope of individual nations, or even small groups of nations. The SKA is therefore being planned from the outset as a truly-global telescope project."

The SKA will be a uniquely sensitive instrument. Its collecting area will be 50 to 100 times larger than today's biggest radio imaging telescopes, the VLA and the GMRT, and 200 times larger than the pioneering Lovell Telescope at Manchester University's Jodrell Bank Observatory (which can be visited



Members of the SKA ISSC at last week's SKA Technical Workshop held at Jodrell Bank Observatory.

quasars, pulsars, gravitational lenses, superluminal motion and the cosmic microwave background. It has led to three of the five Nobel prizes awarded for work in astrophysics, including all those awarded for observational work. Major advances in knowledge can be expected from a new radio telescope with the sensitivity of the SKA.

Radio telescopes have a big advantage over those operating at most

The SKA's superb resolving power- which could extend to one milliarc-second- and exceptional image quality will also provide crucial new information on the formation and early history of stars, galaxies and quasars unaffected by obscuring dust. Its enormously high sensitivity will mean that, for the first time, objects in the early Universe can be studied in detail in the radio range. The SKA is thus the perfect scientific

SKA Configuration

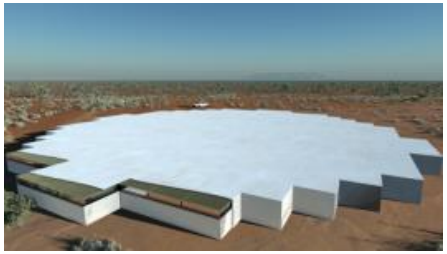
SKA's receptor of 1 M meters with many innovations

5 Continents

Dish
3300×15m
300M-10G

3000 km，extend outwards in spirals

AA_mid
250 × 56 m
400M-1.4G



AA_low
250 × 180m
70M-450M

West Australia

South Africa Karoo

Prime Characteristics

1) Large collecting area (km^2) → sensitivity to detect and image hydrogen in early universe

- ***sensitivity ~ 50 x most powerful telescopes (JVLA, LOFAR)***

2) Large field of view → fast surveying capability over the sky

- ***survey speed ~10^4– 2 x10^6 x JVLA***

3) Wide frequency range required for Reference Science Mission

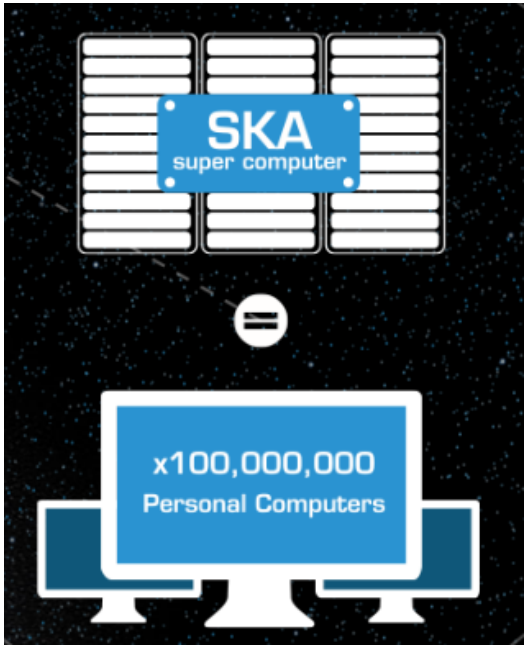
- *low : 70-350 MHz*
- *mid: 350 MHz-10 GHz* *high: 10-25+ GHz*

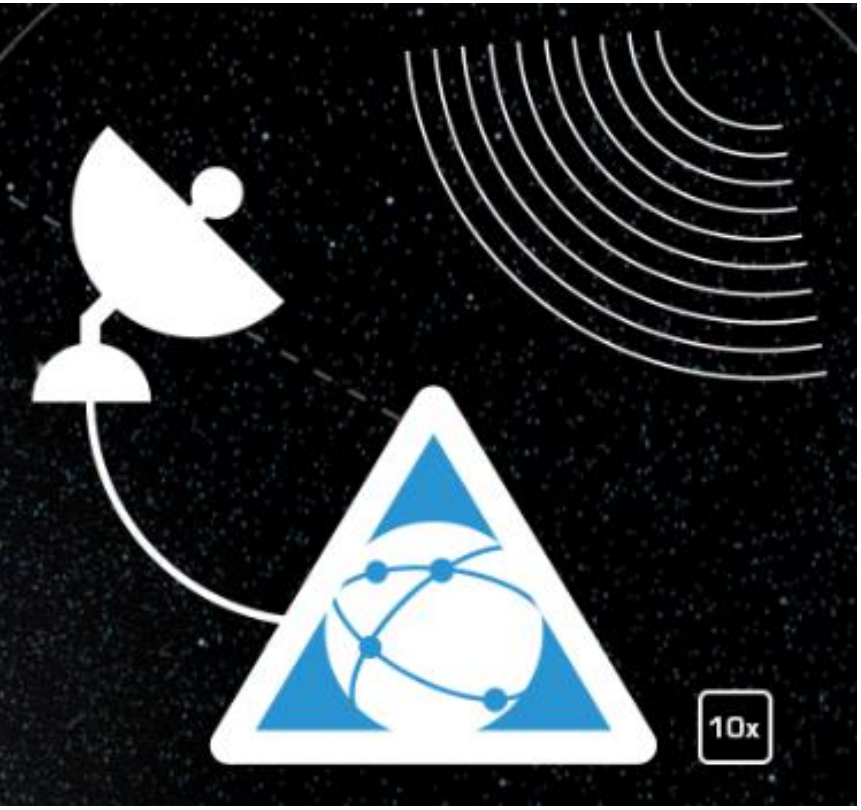
4) Large physical extent (3000+ km) → capability for detailed imaging of compact objects and astrometry with *mas* resolution

Amazing Facts

www.skatelescope.org

- SKA central computer will have processing power of *100 million PCs*.





SKA dishes will produce *10 times* the global internet traffic.

SKA Key Science Drivers

ORIGINS

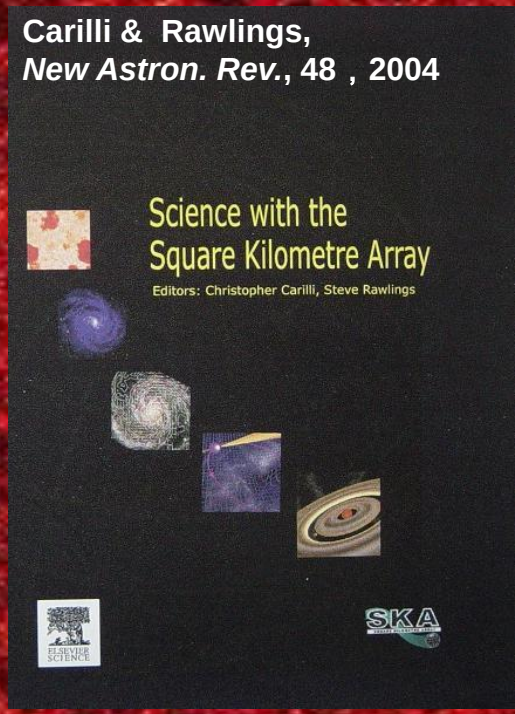
- **Cosmology and Galaxy Evolution**
  Galaxies, Dark Energy and Dark Matter
- **Probing the Dark Ages**
  When & how were the first stars formed?
- **Cradle of Life**
  What are the conditions for life and where can it be found?

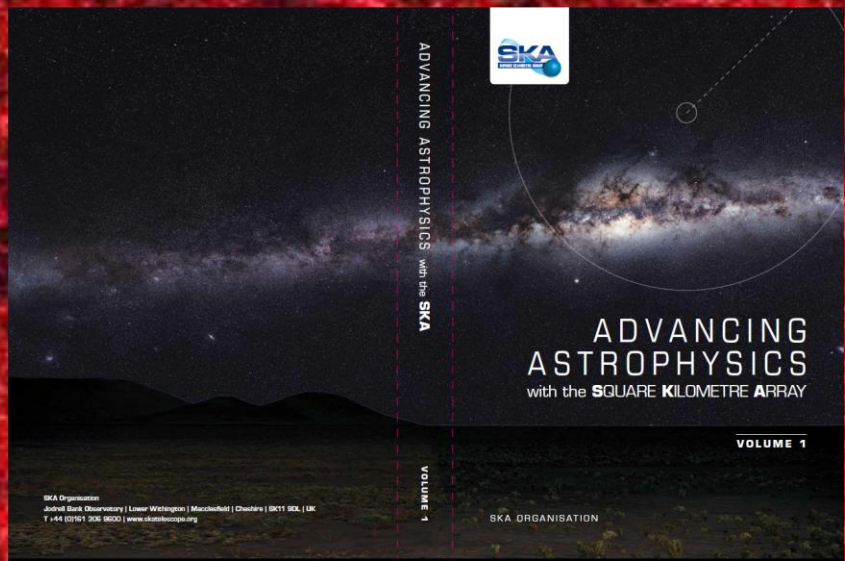
FUNDAMENTAL FORCES

- **Strong-field tests of General Relativity**
  Was Einstein correct?
- **Origin & Evolution of Cosmic Magnetism**
  Where does magnetism come from?

plus **The Exploration of the Unknown** as an underlying philosophy for design & costing

Carilli & Rawlings,
***New Astron. Rev.*, 48 , 2004**





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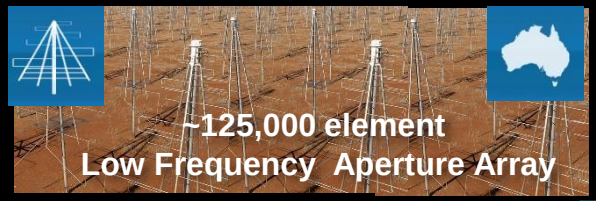
Credit SKAO

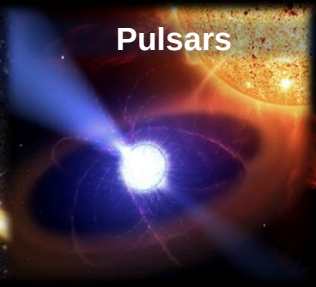
The SKA Rebaseline

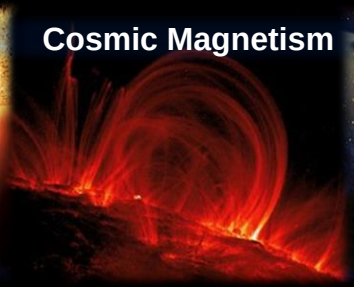
Phase I : 2020

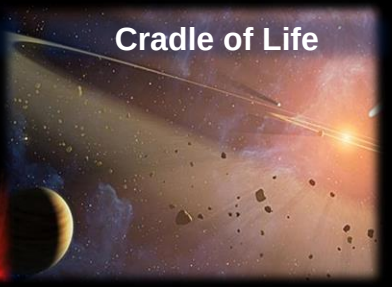


Phase II : 2024

Science

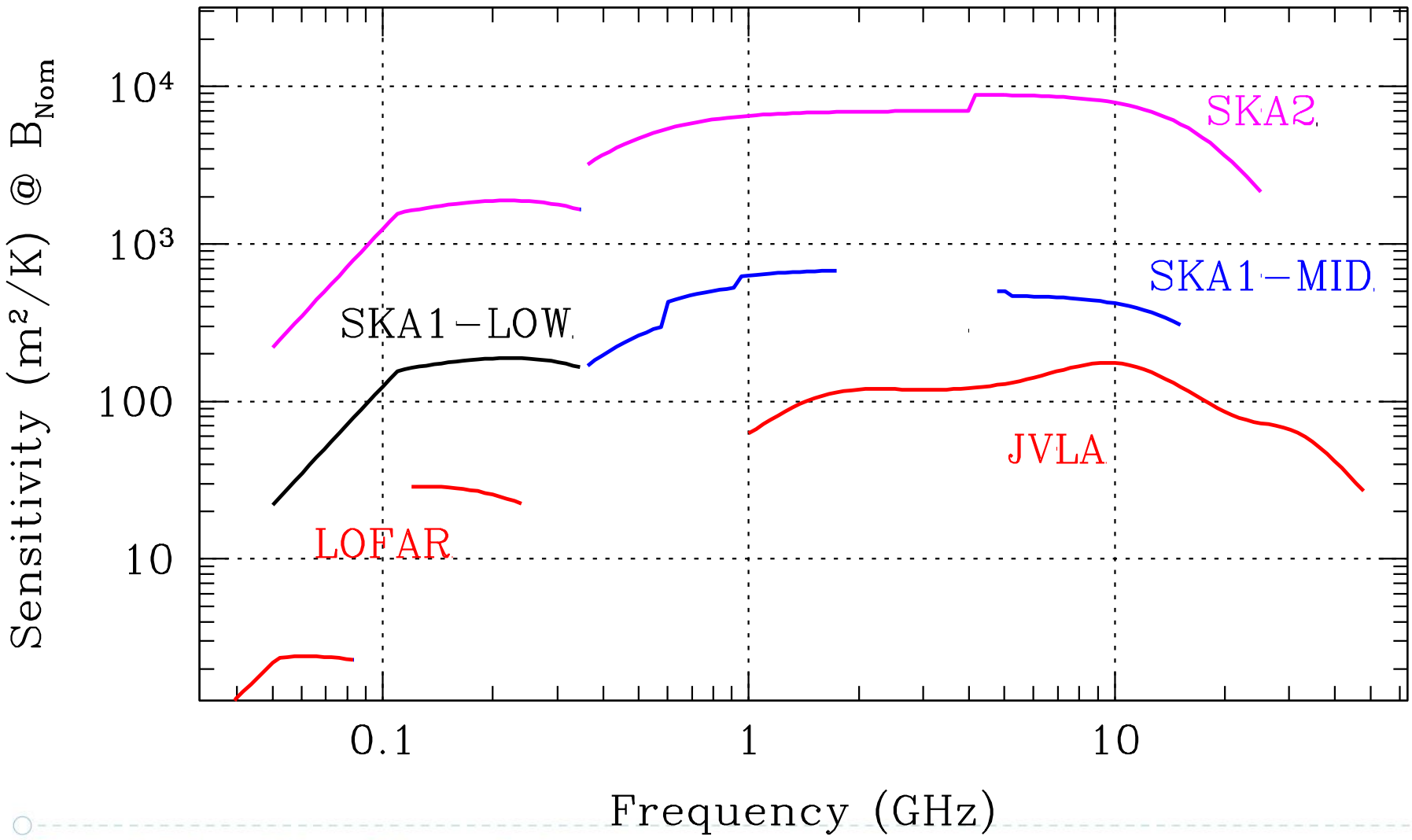






50 MHz 100 MHz 1 GHz 10 GHz

Sensitivity Comparison



SKA1 Rebaseline Comparison

		JVLA (1.4 GHz)	SKA1-MID (1.4 GHz)	FAST (1.4 GHz)	LOFAR-NL (140 MHz)	SKA1-LOW (140 MHz)
Aeff	m2	(7.6×10^3)	2.7×10^4	4×10^4	5.2×10^4	2.5×10^5
Tsys	K	(45)	20	27	600	490
Aeff/Tsys	(m2/K)	168	1330	1480	85	520
FoV	deg2	0.17	0.47	0.021	9	7.1
Survey Speed FoM FoV x $(Aeff/Tsys)^2$	(deg2 m^4/K^2)	4.8×10^3	8.3×10^5	4.6×10^4	6.7×10^4	1.9×10^6
B_{MAX}	(km)	36.4	154	0.3	52	65
Angular Resolution	(arcsec)	1.2	0.28	148	8.5	6.7

Sensitivity： 7.9x JVLA 0.90x FAST 6.1x LOFAR

Resolution： 4.3x 528x 1.3x

Survey Speed： 170x 18x 28x

Credit SKAO

Credit SKAO

A Package of Notional SKA1 Key Science Projects

SWG	Objective
CD/EoR	Physics of the early universe I GM I. Imaging
CD/EoR	Physics of the early universe I GM I. Power spectrum
Pulsars	Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection
Pulsars	High precision timing for testing gravity and GW detection
HI	Resolved HI kinematics and morphology of ~10^10 M_sol mass galaxies out to z~0.8
HI	High spatial resolution studies of the ISM in the nearby Universe.
HI	Multi-resolution mapping studies of the ISM in our Galaxy
Transients	Solve missing baryon problem at z~2 and determine the Dark Energy Equation of State
Cradle of Life	Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc
Magnetism	The resolved all-Sky characterisation of the Interstellar and Intergalactic magnetic fields
Cosmology	Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales.
Cosmology	Angular correlation functions to probe non-Gaussianity and the matter dipole
Continuum	Star formation history of the Universe (SFHU) I+II. Non-thermal + Thermal processes

- Outcome of well-documented SKA1 science prioritisation process
  - All objectives originate with the science community
  - Review and strong endorsement by advisory bodies (SRP, SEAC)
- Should be viewed as ***representative*** package of high-impact science deliverables for the first five years of science operations

Credit SKAO

SKA: driving innovation

Element	SKA1 scale	SKA2 scale
Dishes, feeds, receivers	~200	~2500
Aperture arrays	~130,000	~1,000,000
Signal transport	~1 Pb/s	~10 Pb/s
Signal processing	~exa-MACs	~exa-MACs
High performance computing	~100s tera-flops	~exa-flops
Data storage	Exa-byte capacity	Exa-byte
Power requirements	~10MW	~50MW

Key innovation: Software engineering and algorithm development.

Exa = 10^{18}, or 1 followed by 18 zeroes;
requires increase in compute capability by factor 1000

SKA Timeline

1990→ Individual Proposal

1993→ Preliminary R&D (LTWG)

2000→ Initial Concepts (ISSC)

2008→ System Design and Cost (SSEC)

2011→ SKA Legal Entity (Founding/Governing Board)

Legal Entity/SPO/CoDR

2012→ Pre-construction

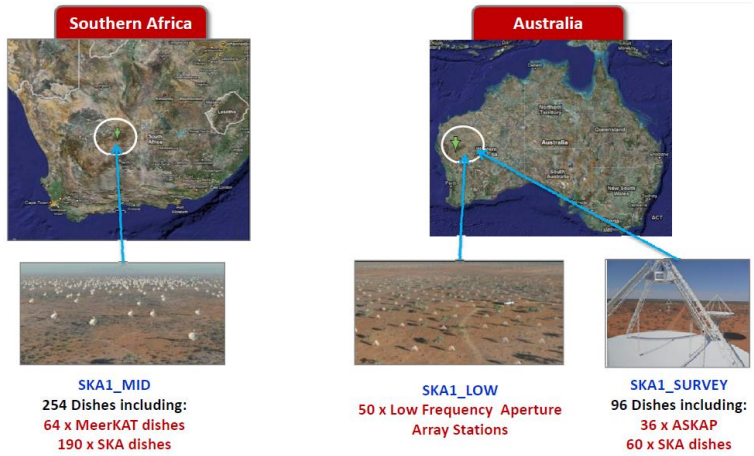
Site Selection/Infrastructure/Detailed Design/Verification

2018→ Phase 1 Construction

10 % SKA, 100 km, 650 M€

2024→ Phase 2 Construction

90% SKA, 3000 km, 5+ B€



Science operations with Phase 1

2030+ Full science operations with Phase 2

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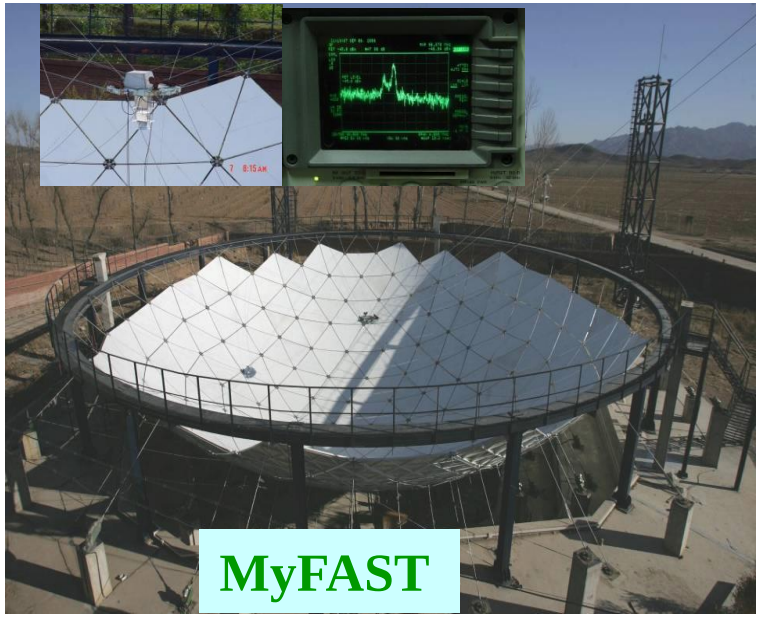
Path of Chinese Radio Astronomy

Miyun 50 m RT

28X9 m MSRT



MyFAST

Site Survey in China

Siting the SKA in China

RFI ?

Proposal for Siting the SKA in China

Dec 31, 2005 !

Main Part

National Astronomical Observatories,

SKA

NAOC

SKA Site Spectrum Monitoring (SSSM)
Data Summary Report

Sites: DaWoDang, ShangJiaChong, ShenAoTang of GuiZhou Province,
MiYun of Beijing,

IAU COLLOQUIUM 182

SOURCES AND SCINTILLATIONS: REFRACTION AND SCATTERING IN RADIO ASTRONOMY

Guiyang City,
Guizhou Province,
CHINA

April 17-21, 2000

Deadline for registration
and abstracts:
February 1, 2000

Contact Add

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Beijing Astronomical Obser
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Beijing 100012

Tel : +86 10 64
Fax : +86 10 64
Email: iauc182@class1.ba
URL: htt

Once every 5 yrs

CRAT2010, + 2016?

R. Nan (co-chair), C. He (co-chair),
C. Jin, L. Shi, X. Xu, L. Zhu, N. Wu, J. Li, Y. Qiu, B. Peng

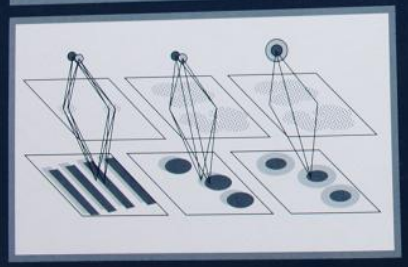
Sponsored by:

IAU URSI

Sources and Scintillations:
Refraction and Scattering
in Radio Astronomy

IAU Colloquium 182

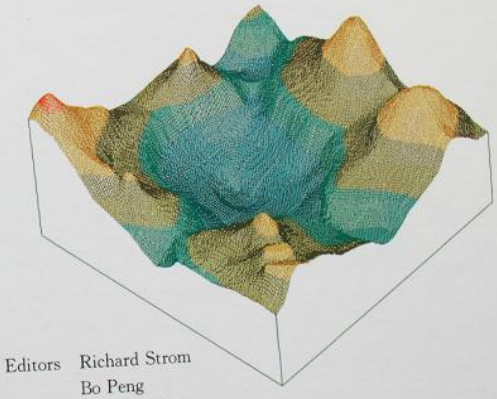
Edited by
Richard Strom, Peng Bo,
Mark Walker and Nan Rendong



Kluwer Academic Publishers

the 3rd Meeting of
THE LARGE TELESCOPE WORKING GROUP

and of
a Workshop on
SPHERICAL RADIO TELESCOPES
2 – 3 October 1995, Guizhou, China



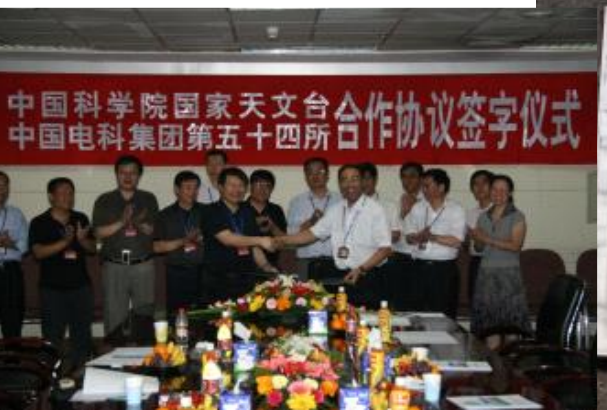
Editors Richard Strom
Bo Peng
Rendong Nan

International Academic Publishers

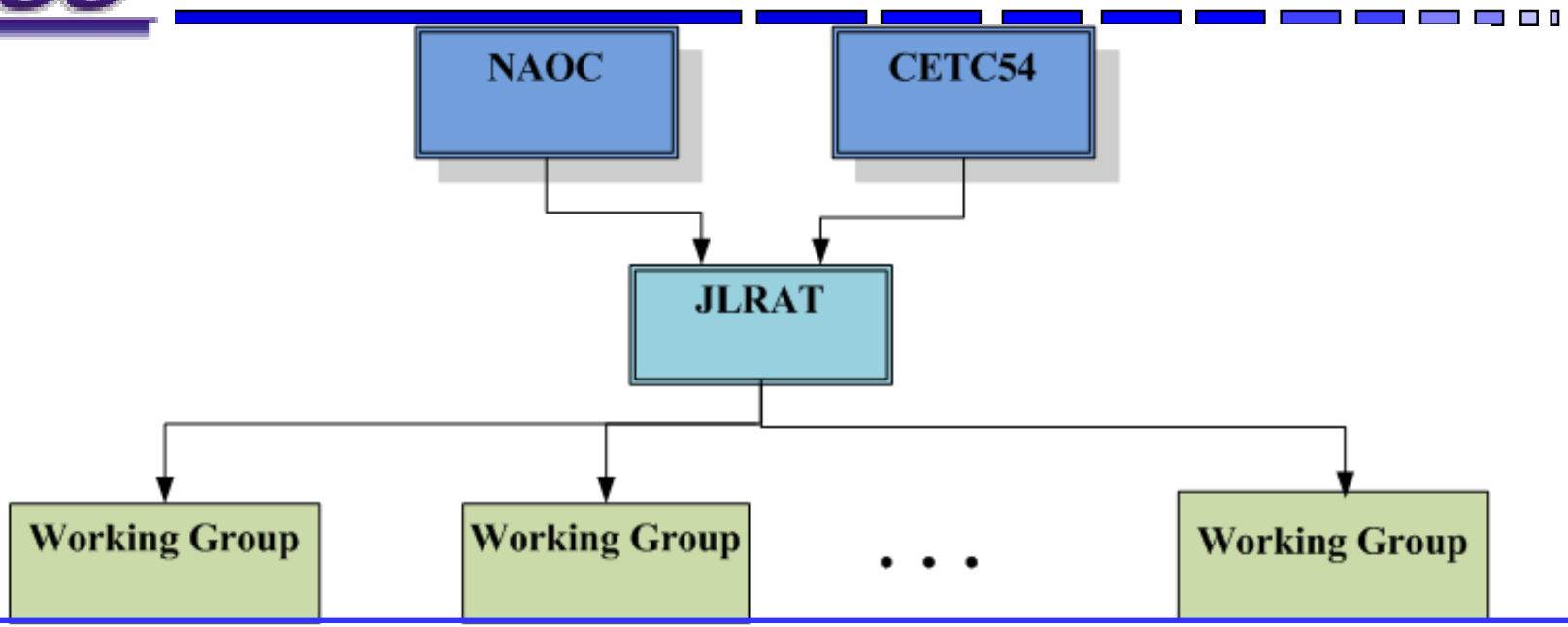
Establishment of the JLRAT

NAOC and CETC54 established JLRAT (Joint Laboratory for Radio Astronomy Technology) in January 2010, to

- **find more active ways to contribute to the SKA project；**
- **explore a new mode to establish and develop a radio astronomy technology laboratory；**
- **train new generation of radio astronomical engineers by making use of existing resources in both institutions.**



JLRAT Structure



1. DVAC Group
2. PAF Group
3. Feed Design and Manufacture Group
4. mm & Submm Antenna Technology Group
5. Large Telescope Antenna Design, Manufacture and Measurement Group
6. Radio Spectrum Monitoring Group
7. EMC Research Group
8. FAST Structure Research Group
9. "TianLai " Project Group

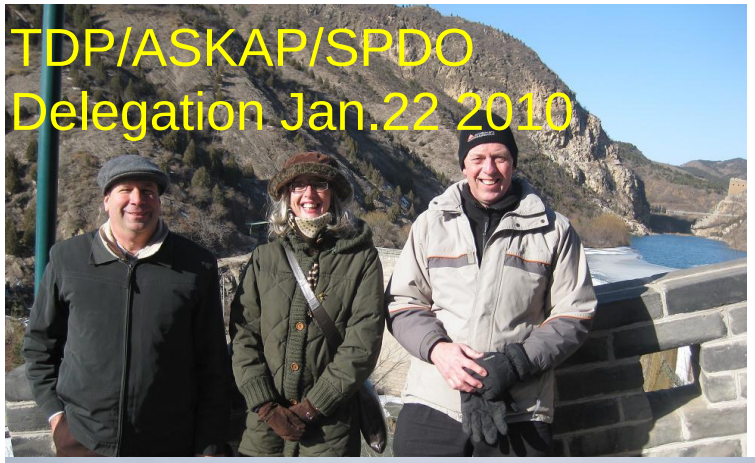
Promote Regional SKA Activities

- Japan, Korea and China meet at MeerKAT Support Base Feb. 2009, common interest to form East Asian SKA Consortium
- Skype telecon Sept.2009, national status + discuss regional SKA interests informally

Workshop on East Asian Collaboration for SKA, Daejeon,1129-1203 2011

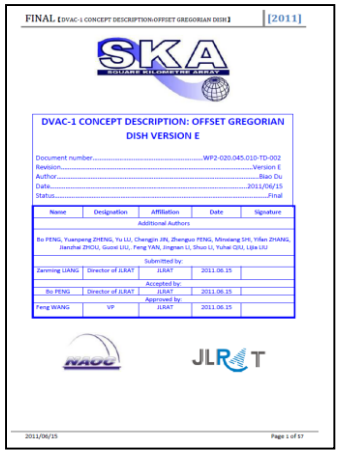
International Activities

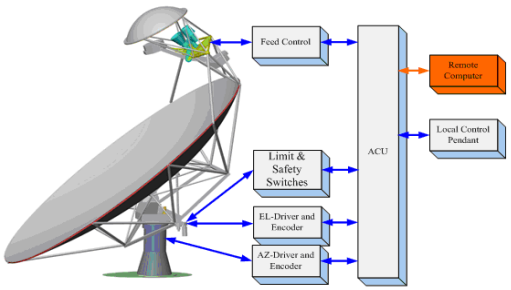
Telecon CoDR, Mar.17 2011, JLRAT, SPDO & CSIRO
Requirements spread sheets, CoDR doc list, temp
Workshop on preparing two CoDR docs, 27th Mar. 2011
DVAC_1 & 2 for Offset Gregorian & Axi-symmetric dish

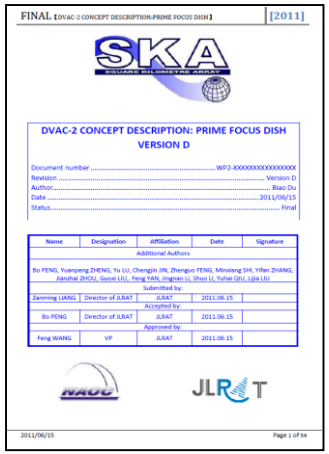


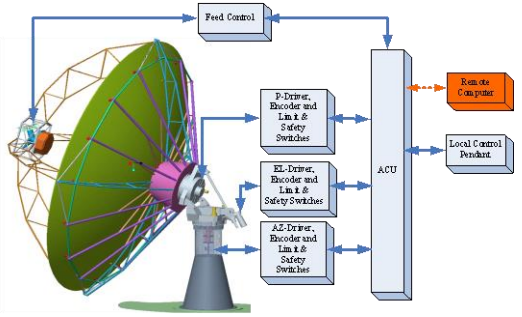
SKA Dish CoDR

- July 13-15,2011 at DRAO
- **Presentations：**
  - DVAC Concept Description：
  - DVAC-1 (Offset Grgorian)和DVAC-2（Prime Focus），
  - DVAC Concept Logistical Engineering，
  - Cost Estimates and Plans for the PEP Phas
  - DVAC Risks and Their Mitigation









SKA
SQUARE KILOMETRE ARRAY

JLRT

Square Kilometre Array

Janimaarnu中国人

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Chinese Long Involvement

- Co-Proposer
- **Funding Board, 9 Signatures**
- **Establish SKAO, 7 Initiators**
- ASKAP
- SKA Dish Verification Antenna China

EXECUTED by
Signed by Belinda Brown,)
New Zealand Deputy High)
Commissioner
to the United Kingdom and Ireland
for and on behalf of
The Government of New Zealand, acting by and through Ministry of Economic Development, New Zealand)

Signature

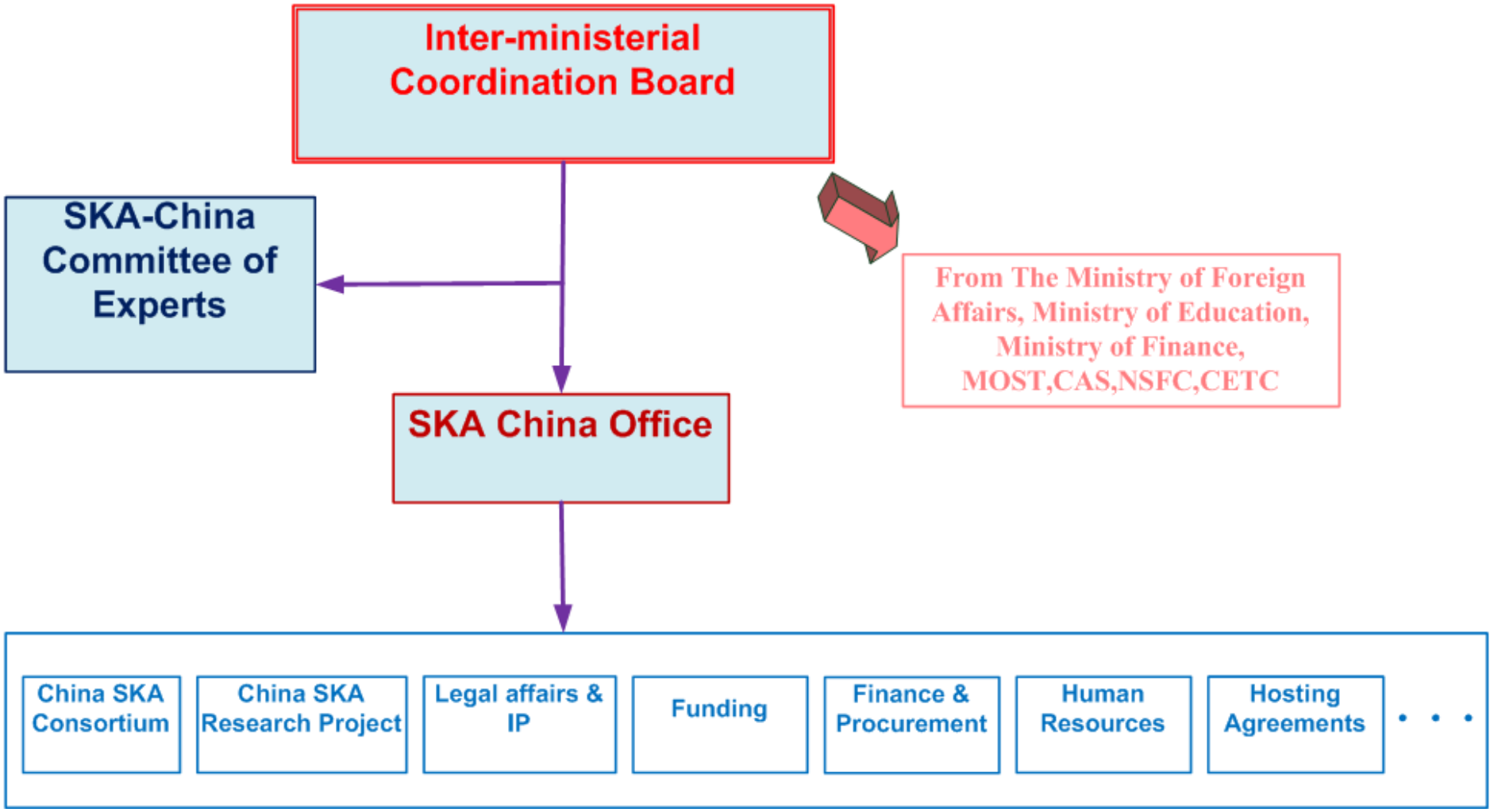
EXECUTED by
Signed by Dr. Bernie Fanaroff)
for and on behalf of)
National Research Foundation, South Africa)

Signature

EXECUTED by
Signed by Prof. Dr. John Womersley)
for and on behalf of)
Science and Technology Facilities Council, United Kingdom)

Signature

SKA China Governance



Credit SKAO

International Design Teams

Project Management and System Engineering Team based at JBO, UK.
~500 scientists & engineers in institutes and industry in 11 Member countries.

China's participation in SKA

Positions in SKAO

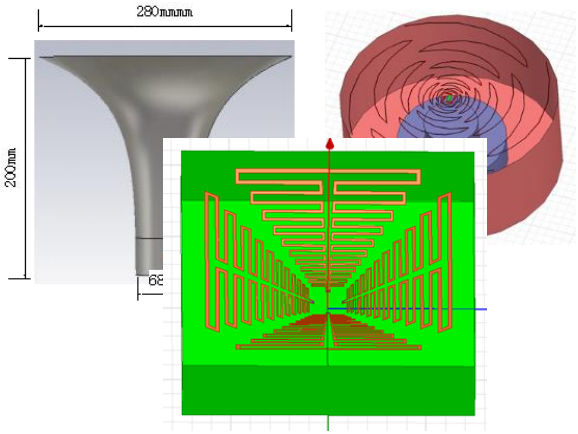
General Meeting	**Nominated representative**	**Second Representative**
	CHEN Linhao (MOST)	PENG Yiqi (MOST)
Board of Directors	**Voting Representative**	**Science Representative**
	YIN Jun (MOST)	PENG Bo (NOAC)
Hosting Agreements	**Negotiation team Member**	**Task Force Member**
	WANG rongfang (MOST)	ZHAO Jing (MOST)
Funding Task Force	**Member**	
	QIN Bo (NAOC)	

Response to the Request for Proposals (RfP)

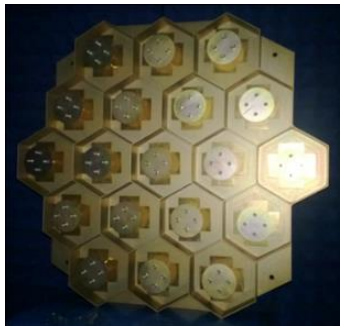
Work Package	Dish	CSP	SDP	TM	SADT	LFAA	MFAA	AIV	Infra	WBSPF
CHINA	√		√		√	√	√			√

Technology Study in Pre-construction Phase

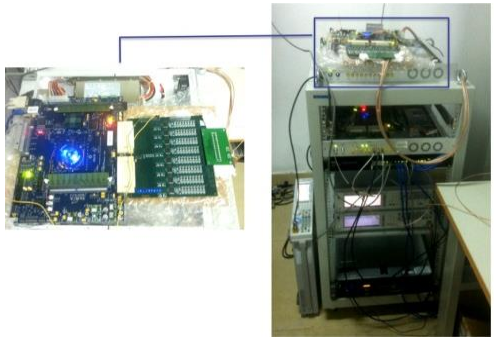
- JLRAT/NAOC Coordinating Chinese activities in the RfP (Request for proposal) processes. China plays roles in 6 (of 10) SKA Work-packages.
  Leading the low frequency band of WBSPF Work-package.
- Promoting Wideband single pixel feeds advanced research, PAF experiment on 4.5 m telescope, Digital beam-forming network experiment.
- Designing MMIC, hybrid LNA and Cryostat, and the Turbo-Brayton cooler for RA
- Fabricating & Assembling 18 m*15 m single-piece composite reflector DVAC



Simulation on WBSPF



PAF prototype



Digital beamforming network prototype

Assembly of DVA-C

Participating Int'l SKA WGs

15 Chinese join 10/11 SKA Science WGs，2 Co-Chairs

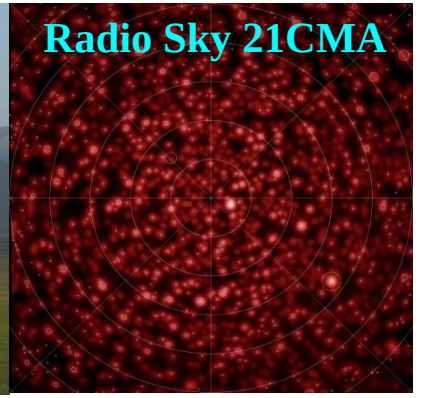
Science WG	Chairs	Chinese attendance
Epoch of Reionization	Leon Koopmans（NL）， Jonathan Pritchard（UK）	陈学雷（国台）
Pulsars	Ben Stappers （UK）， Michael Kramer （DE）	韩金林(国台)、李柯伽（北大）、 代实（北大）、邵立晶（北大）
HI Galaxy Science	Erwin de Blok (NL)，Martin Meyer(AU)	朱明、李菂、田文武（国台）
Cosmology	Mario Santos（SA/Portugal）， Xuelei Chen（China）	赵公博(国台)
Magnetism	Melanie Johnston-Hollitt （NZ）， Russ Taylor（SA）	韩金林（国台）
Cradle of Life	Melvin Hoare （UK），Di Li (China)	金乘进（国台）
Continuum Survey	Isabella Prandoni （IT）， Nicholas Seymour （AU）	陈如荣（国台）
Our Galaxy	Mark Tompson(UK),Grazia Umana(IT)	刘彬 （国台）
Transients	Rob Fender (UK)， Jean-Pierre Macquart(AU)	田文武（国台）、王灵芝（国台）、余文飞（上海台）
Solar & Heliospheric Physics	Eduard Kontar(UK)，Divya Oberoi(IN)	刘丽佳（国台）
Extragalactic Spectral Line	Rob Beswick(UK), Jon Conway(SE)	

Science Preparation for the SKA

1. SKA Pathfinder – 21CMA

10287 antennas @ 4x6 km arms

50-200MHz aims at EoR

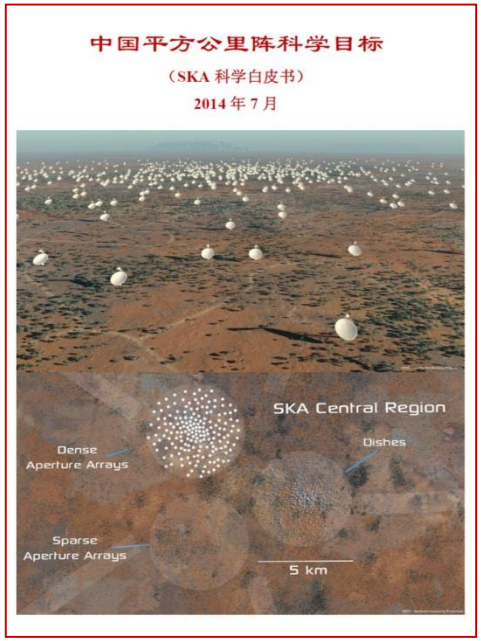


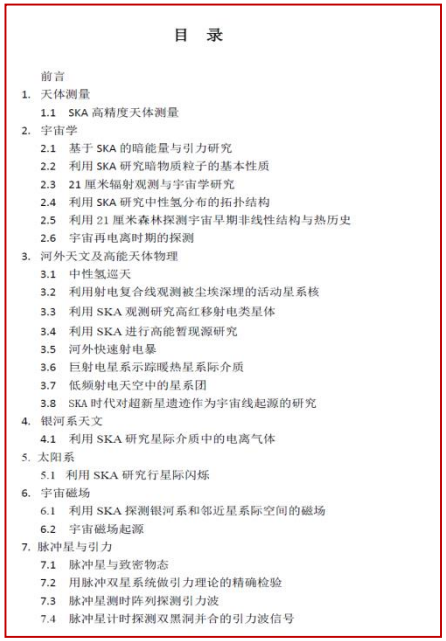
2. Chinese SKA Science Book

Complete in 2015

3. Active participation in the Int'l SKA Science Book

~50 Chinese authors involved, submitted 30 chapter proposals of 170





目 录

Training the next generations

4. China-Australia Joint SKA PhD Program

established in 2013, Co-supervision of PhD students
Some students already started study in Australia
CN-UK, CN-NL programs under discussion

ICRAR International Centre for Radio Astronomy Research

ICRAR AT
THE UNIVERSITY OF WESTERN AUSTRALIA

MASTERS & PHD PROJECTS

5. Chinese SKA Summer School Series

held yearly since 2013
NZ joined China since 2014
SA joined China since 2015
SKAO providing partial support

2013 Chinese SKA Summer School

2014 China-NZ Joint SKA School

2015 CN-NZ-SA SKA Summer School

Outline

1 SKA Introduction

- Characteristics and Science Drivers
- Rebaseline and Timeline

2 Chinese SKA Participation

- National, Regional, International

3 Chinese Involvement in Pre-Construction Phase

4 FAST Concept and Construction

- Feasibility Studies

What is FAST

Five-hundred-meter Aperture Spherical radio Telescope

- Unique Karst depression as the site
- Active main reflector
- Cable - parallel robot feed support

Five hundred meter Aperture Spherical Telescope

Key Science Cases

Neutral Hydrogen line (HI)

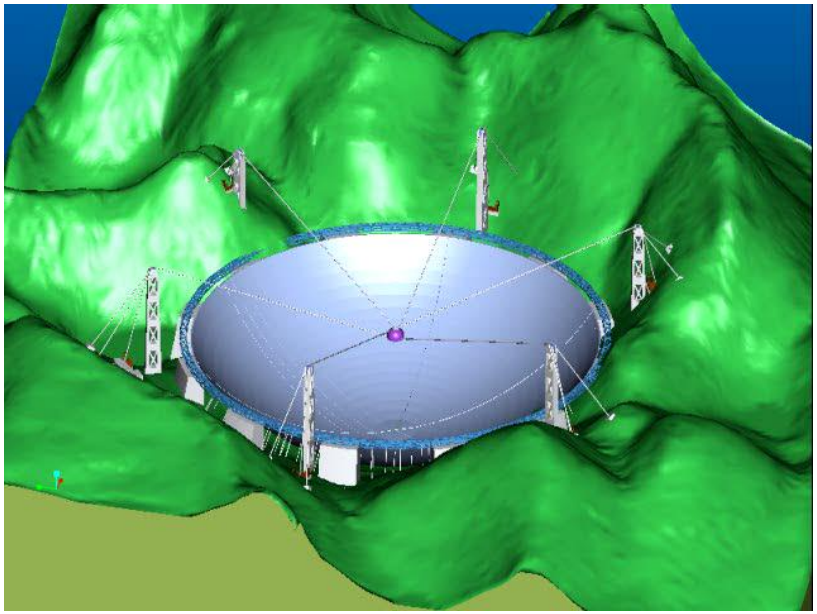
Molecular lines

Pulsar research

Ground support for space exploration

Joining VLBI network

SETI



HI detection on Sept.6 2006 @ MyFAST

- R～300m,D～500m, D_{eff}=300m
- Maxi zenith angle 40°
- Freq. 70MHz-3GHz up to X-band
- Sensitivity 2000 ㎡/K
- Resolution 2.9’;
- Multibeam 19

Site Engineering

Dawodang Original

FAST Funding Proposal approved on July 10 2007

Dawodang Yesterday

FAST shape in 2013 Sept.

FAST shape in 2014 Dec.

3.5 years in 5 mins

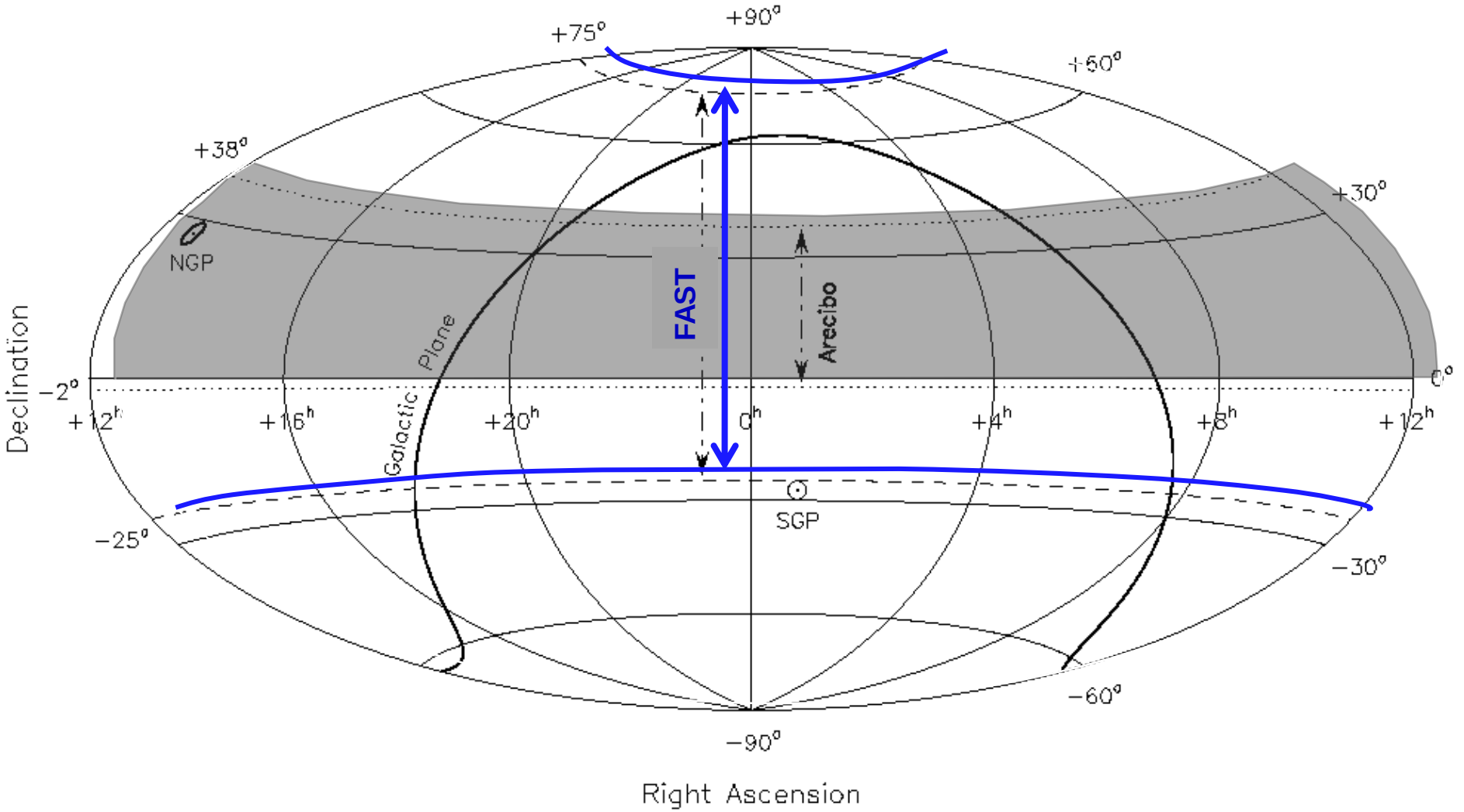
FAST shape in 2015 Feb.

First panel 2015 Aug.

First panel in place 2015 Aug.

FAST panels today 2015 Sept.

FAST Science Capacity



FAST Early Sciences

Telescope may not work appropriately,

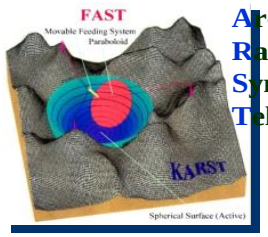
special receiver planned for LF observations:

SPF 270 – 1620 MHz

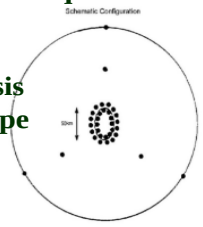
- **Pulsar Search *in M31, Globular cluster***
- **Orion Spectral line survey**
- **HI distribution of nearby disk galaxies**
- **。 。 。 。 。 。**

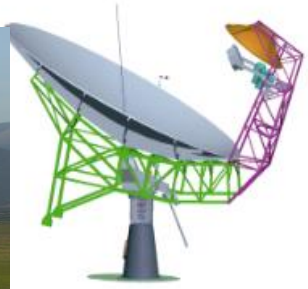
Long March to FAST & SKA

- Co-initiator of LT(1993)➡ Engineer concept KARST (1994, result in FAST) ➡Potential site ➡ Co-founder of SKA funding board (Apr. 2011) ➡Initial member of SKAO (Nov. 2011)➡ Technical development & design (currently)



Kilometre-square Area Radio Synthesis Telescope

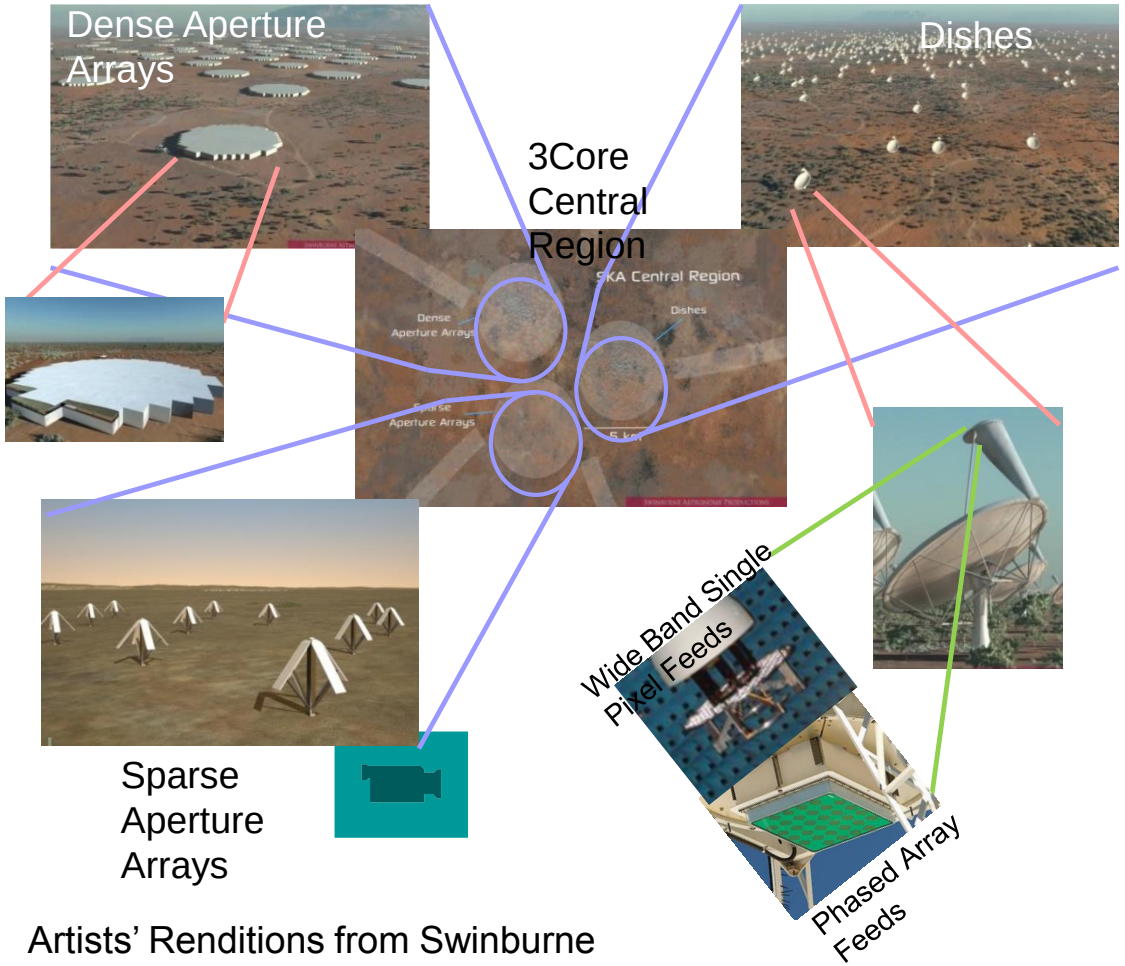




Gordon recalled the skeptics **"We were young enough that we didn't know we couldn't do it"**

If you dream, have big dreams. And have talented supporters to help you.

SKAO Treaty Org



Artists' Renditions from Swinburne

Thanks!