



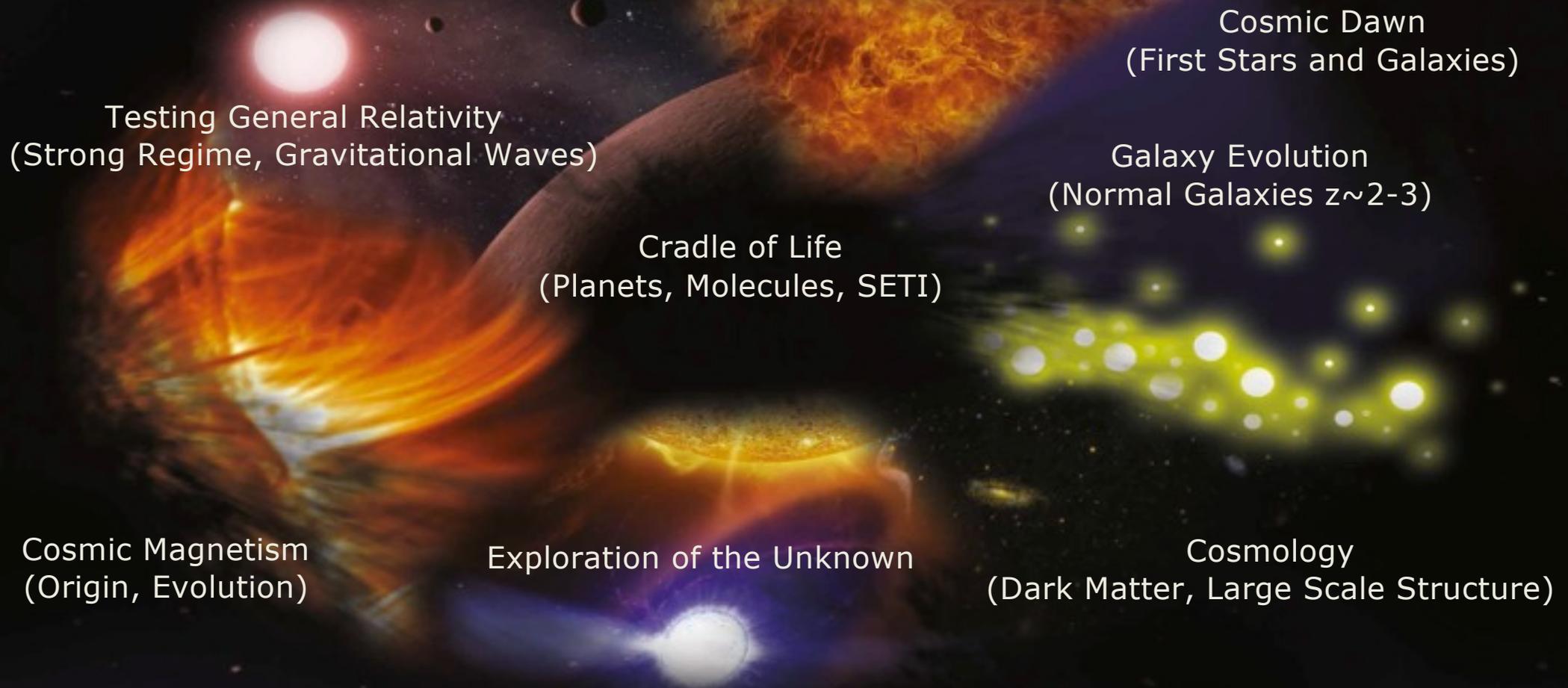
# SKA Science Capabilities

Robert Braun, SKAO Science Director

8 September 2021



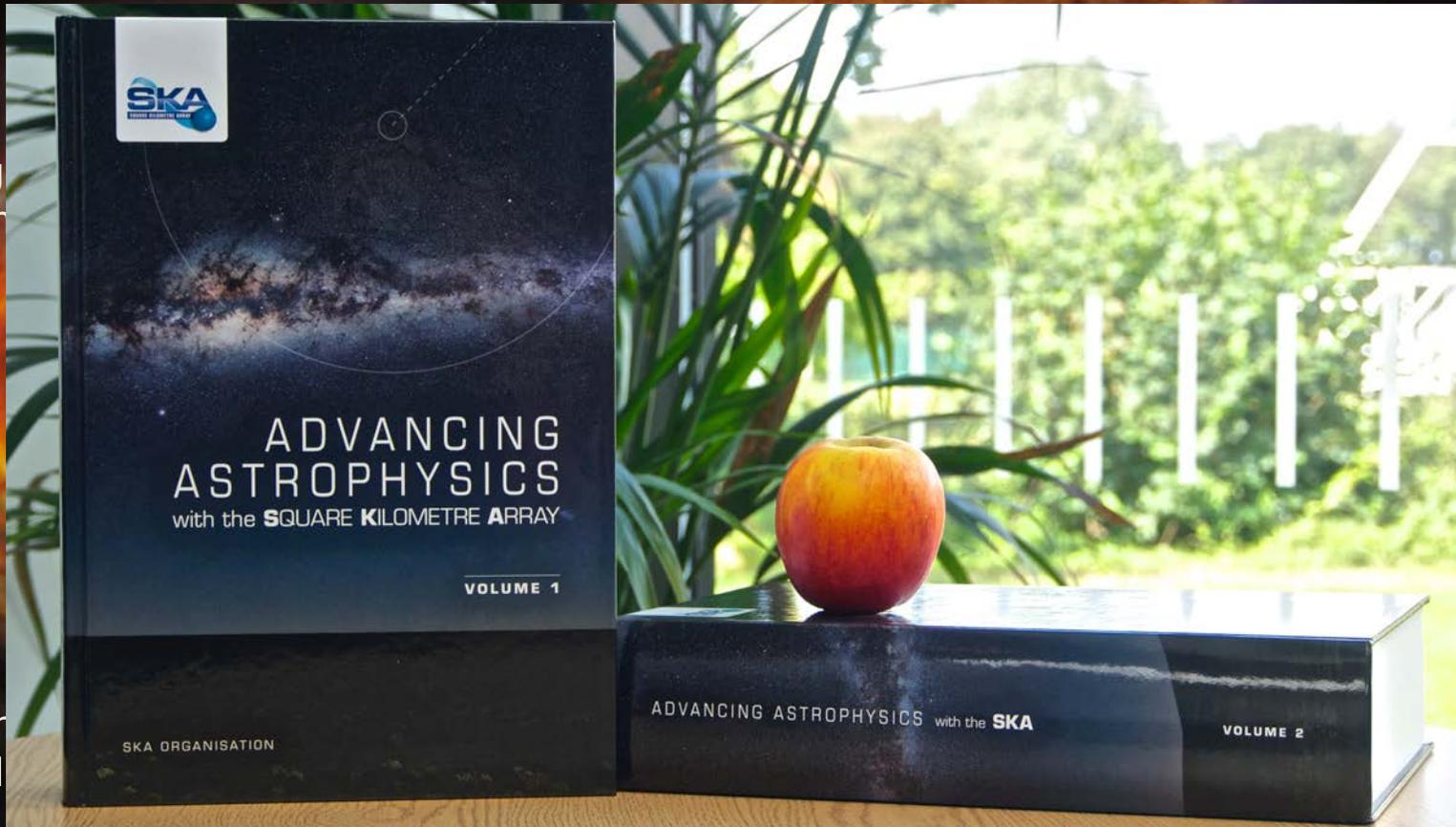
# SKA– Key Science Drivers: The history of the Universe



# SKA– Key Science Drivers: The history of the Universe

Testing  
(Strong Region)

Cosmic Magn  
(Origin, Evol



awn  
(Galaxies)

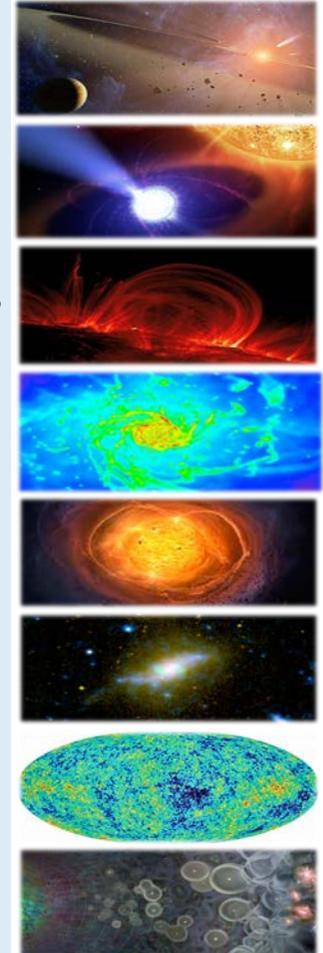
n  
(2-3)

(le Structure)

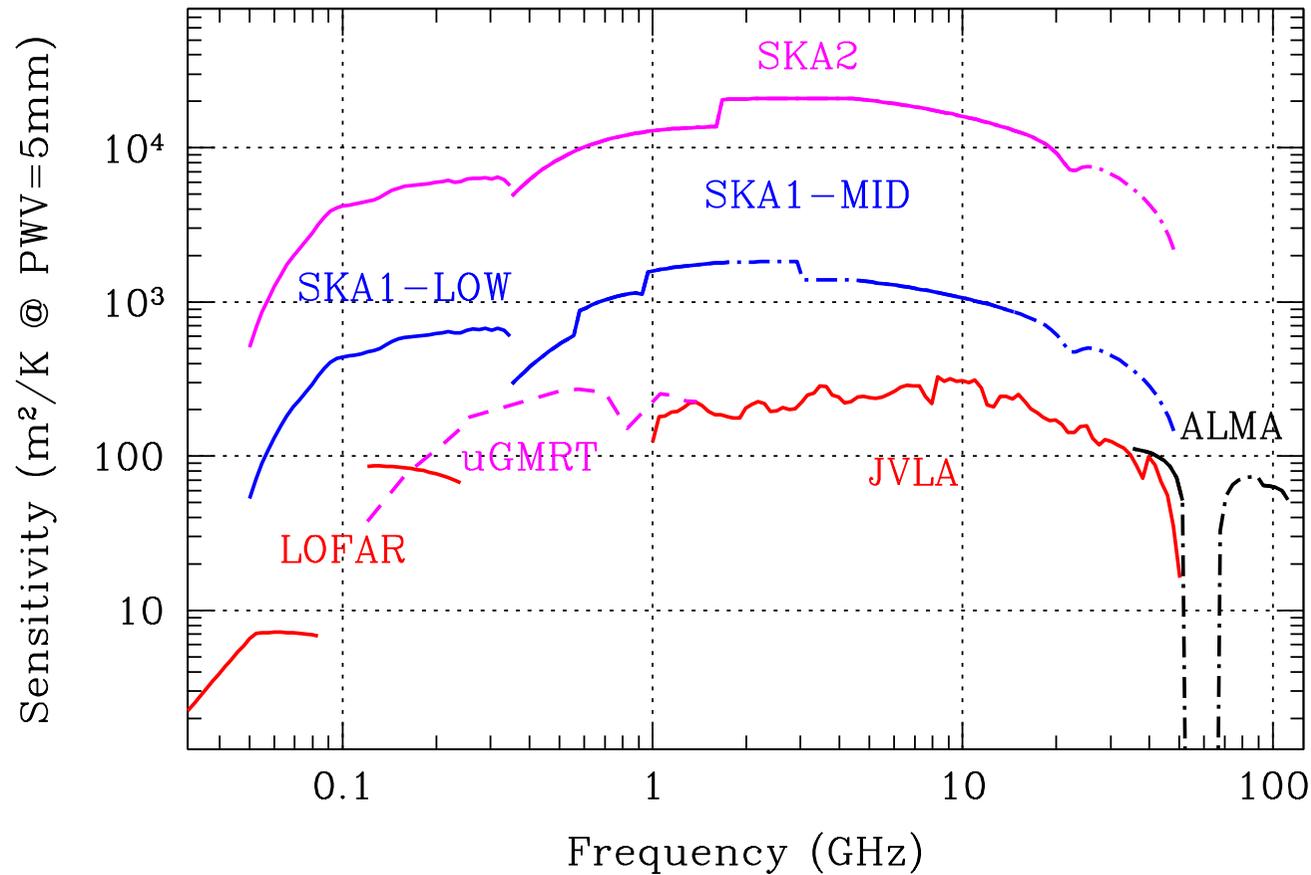
Extremely broad range of science!

# Some of the big SKA Science questions

- **The Cradle of Life & Astrobiology**
  - *How do planets form? Are we alone?*
- **Strong-field Tests of Gravity with Pulsars and Black Holes**
  - *Was Einstein right with General Relativity?*
- **The Origin and Evolution of Cosmic Magnetism**
  - *What is the role of magnetism in galaxy evolution and the structure of the cosmic web?*
- **Galaxy Evolution probed by Neutral Hydrogen**
  - *How do normal galaxies form and grow?*
- **The Transient Radio Sky**
  - *What are Fast Radio Bursts and how can we best utilise them? What haven't we discovered?*
- **Galaxy Evolution probed in the Radio Continuum**
  - *What is the star-formation history of normal galaxies?*
- **Cosmology & Dark Energy**
  - *What is dark matter? What is the large-scale structure of the Universe?*
- **Cosmic Dawn and the Epoch of Reionization**
  - *How and when did the first stars and galaxies form?*



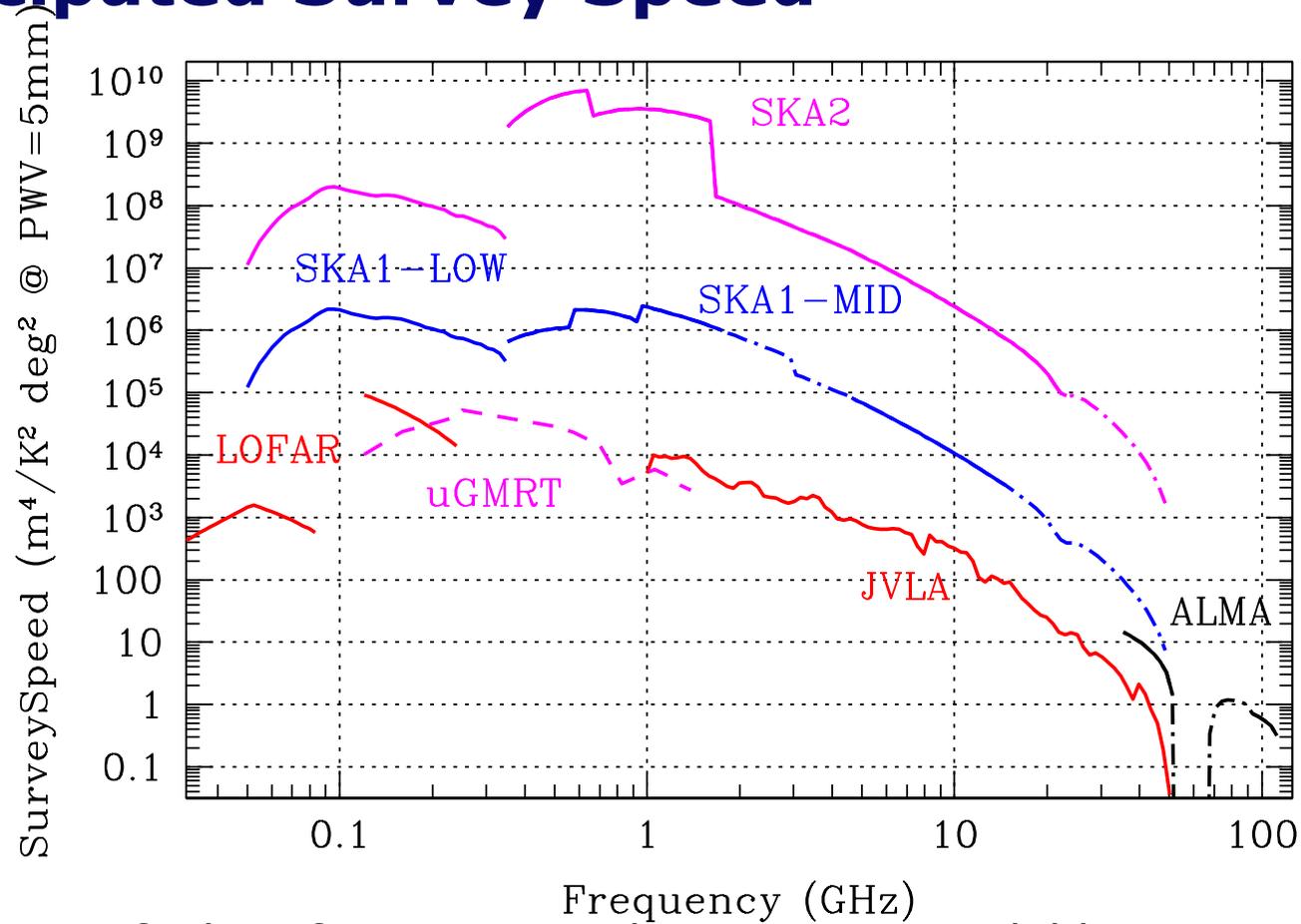
# SKA Anticipated Sensitivity



- Proto-type verified performance predictions now available at most frequencies
- Opportunity for seamless interface of SKA to ALMA capabilities



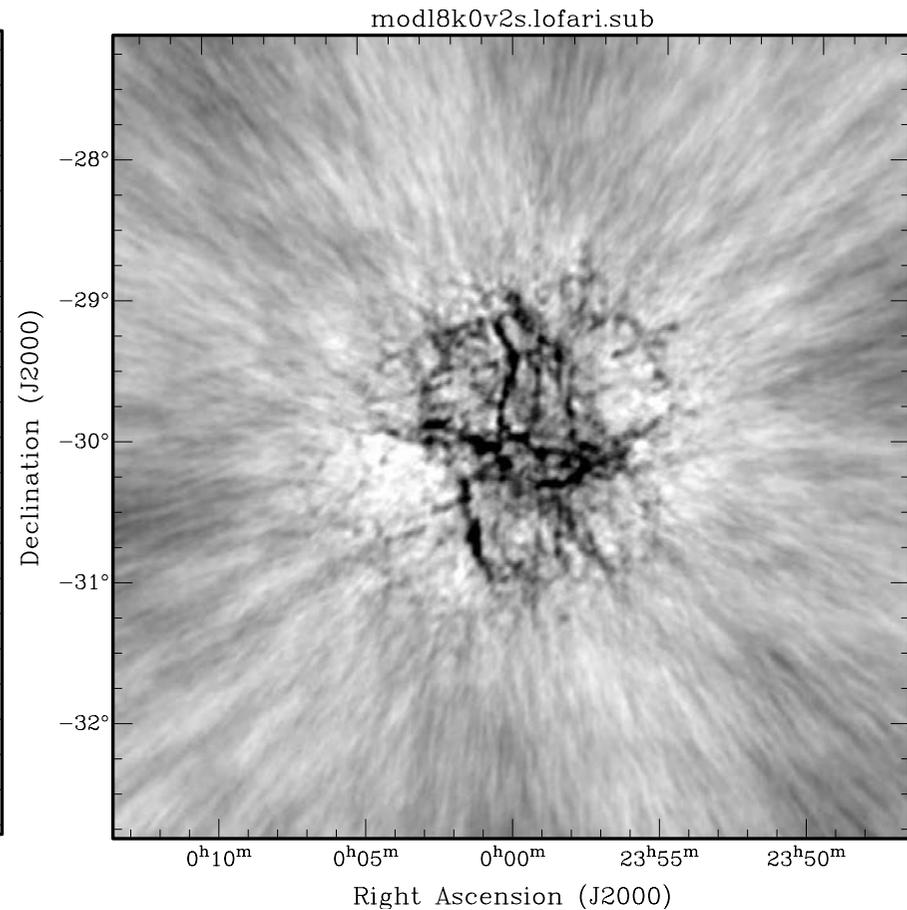
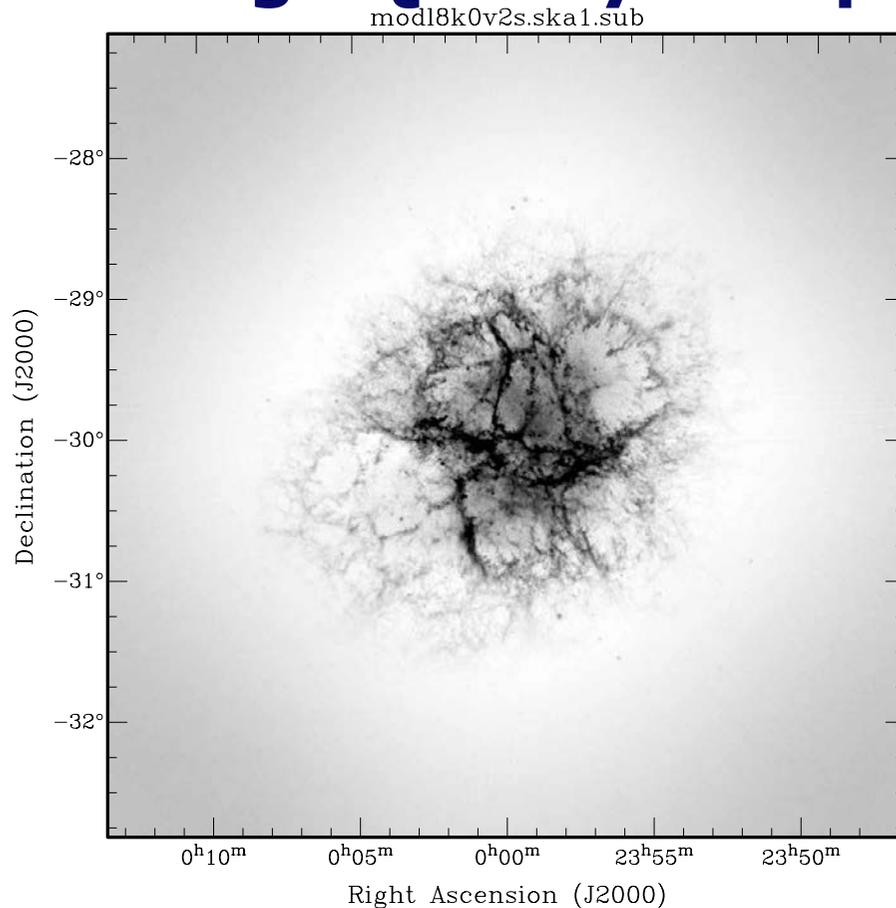
# SKA Anticipated Survey Speed



- Proto-type verified performance predictions now available at most frequencies
- Opportunity for seamless interface of SKA to ALMA capabilities



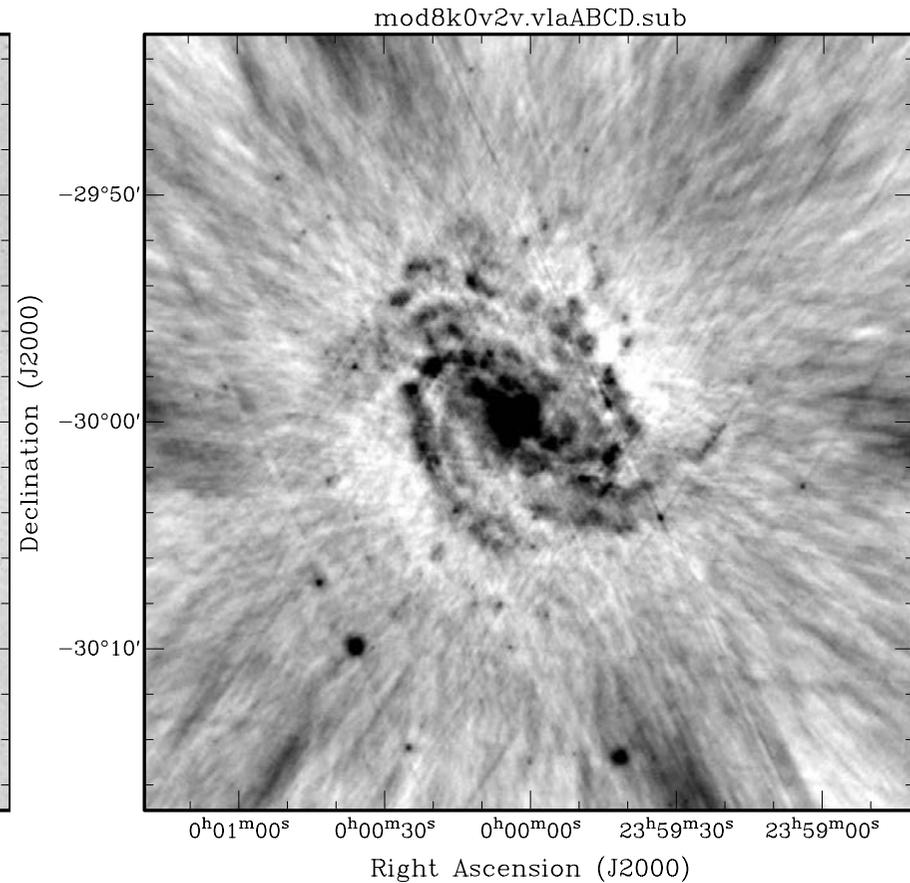
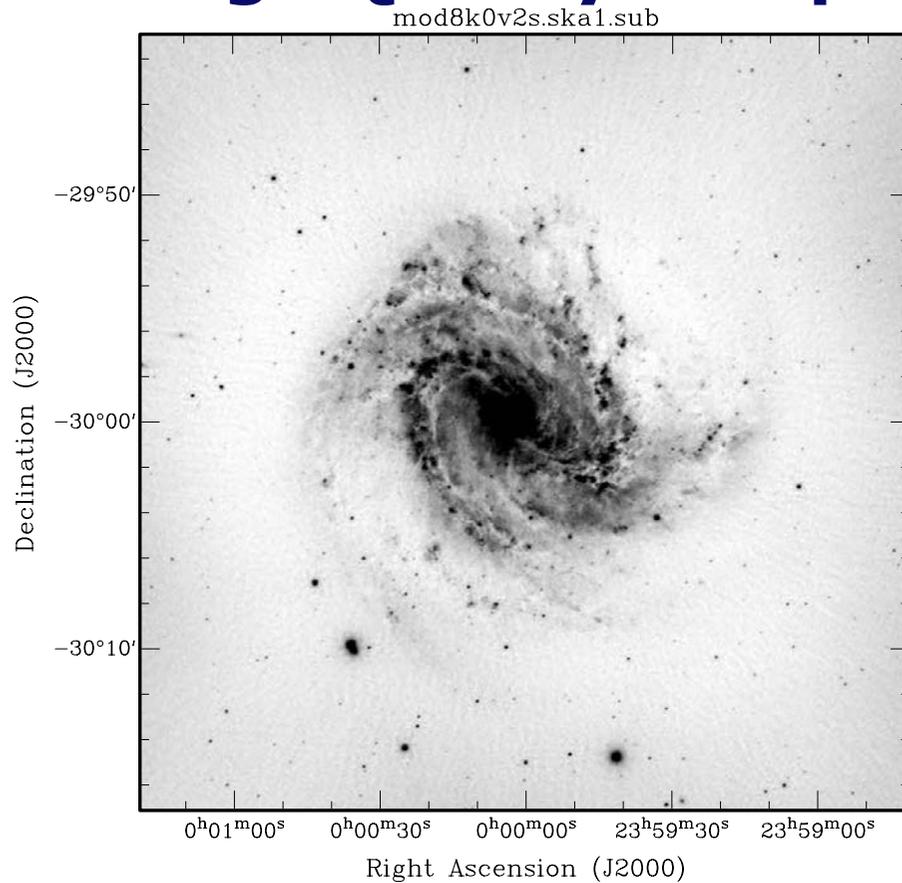
# SKA Image Quality Comparison



- Between 10 and 100 times the image **fidelity** of current facilities
- Single SKA1-Low “dirty” snap-shot compared to LOFAR “dirty” snap-shot



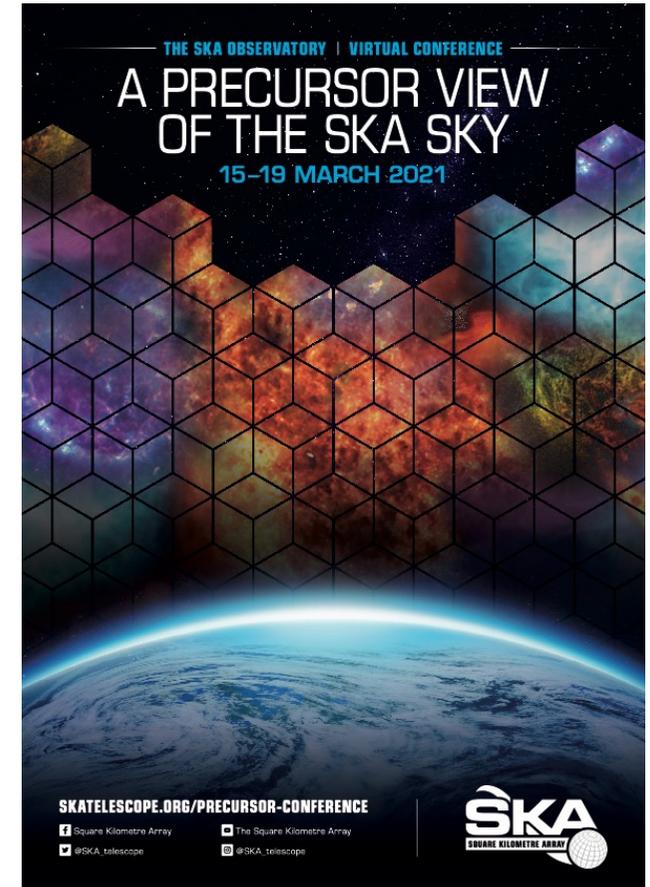
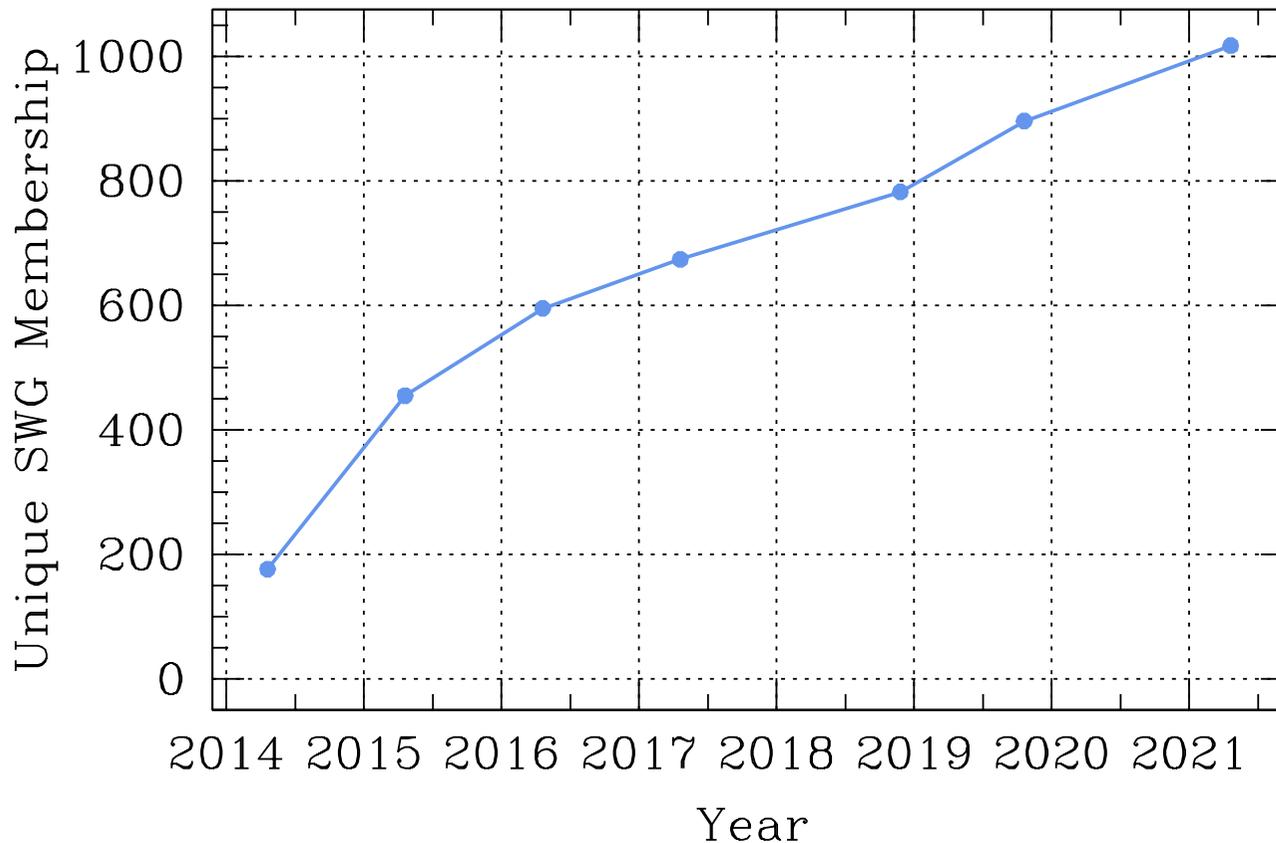
# SKA Image Quality Comparison



- Between 10 and 100 times the image **fidelity** of current facilities
- Single “dirty” SKA1-Mid vs. four “dirty” snap-shots, one in each of JVLA A+B+C+D



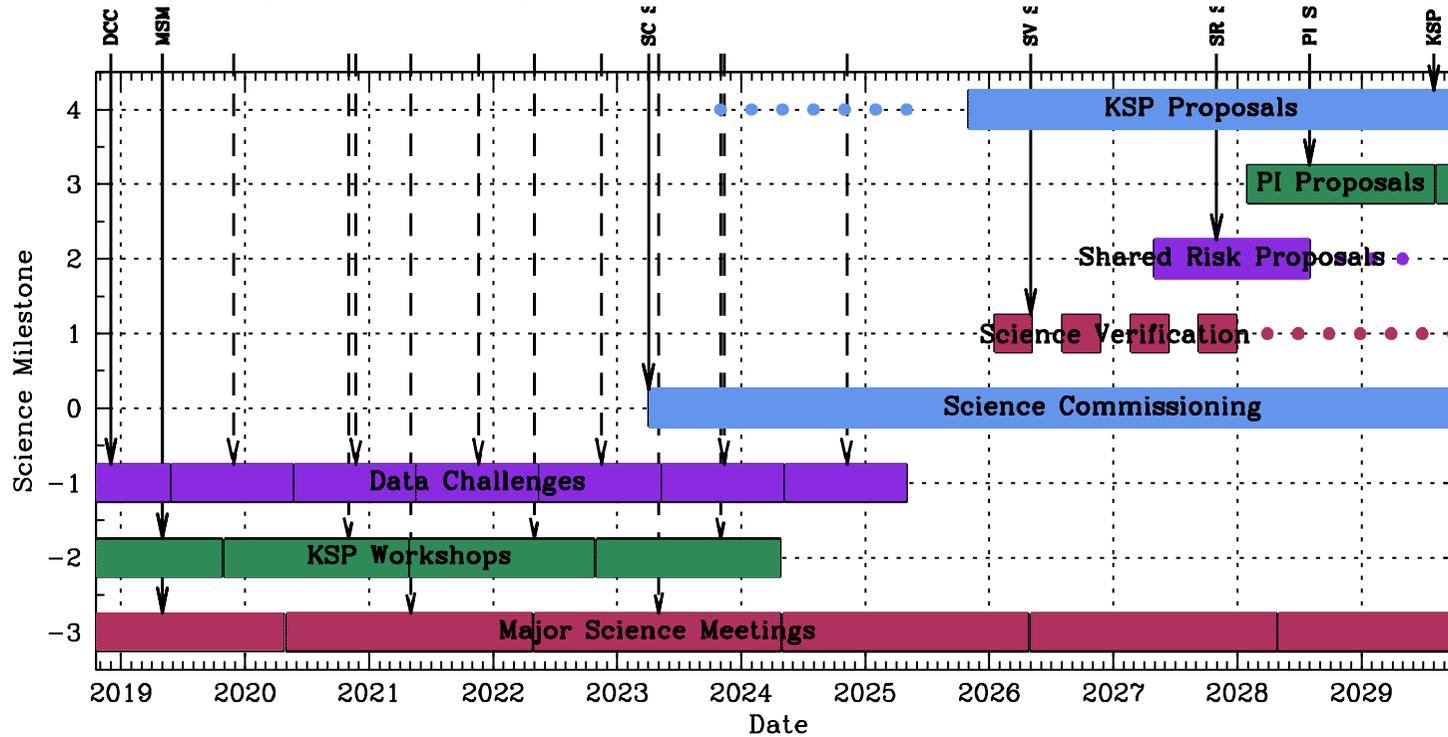
# The SKA Science Community



- SKA Science Working Group membership has grown dramatically, to > 1000
- SKA 2021 Science Meeting, 968 attendees from 36 countries

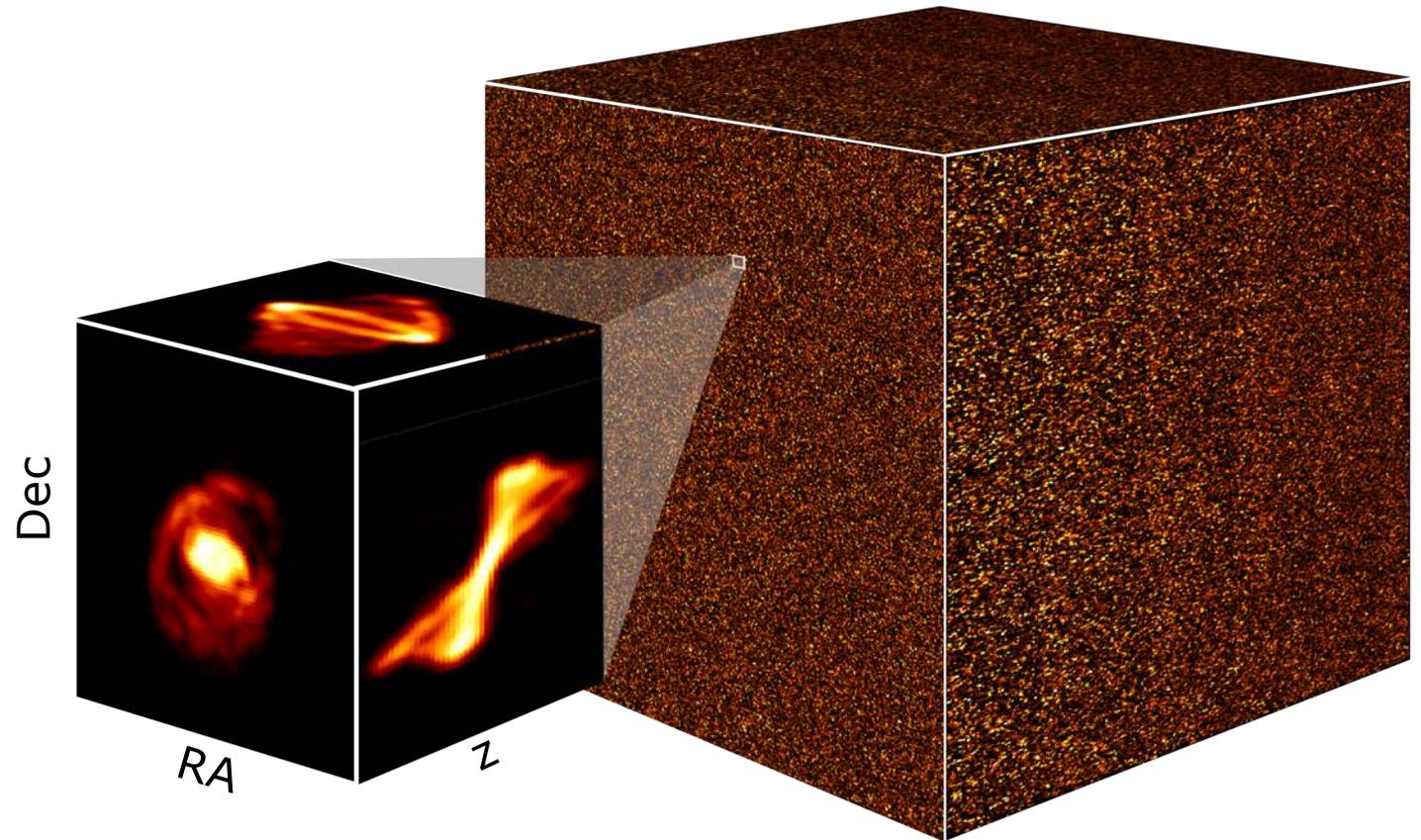


# The SKA Science Timeline



# Science Data Challenge 2 (SDC2)

- Simulated HI Survey
  - $z = 0.24 - 0.5$
  - $20 \text{ deg}^2$  FoV
  - $7 \text{ arcsec} / 30 \text{ kHz}$  resolution
  - $2000^{\text{h}}$  simulated integration
  - 1 TB Data Product size
  - Source finding & characterization



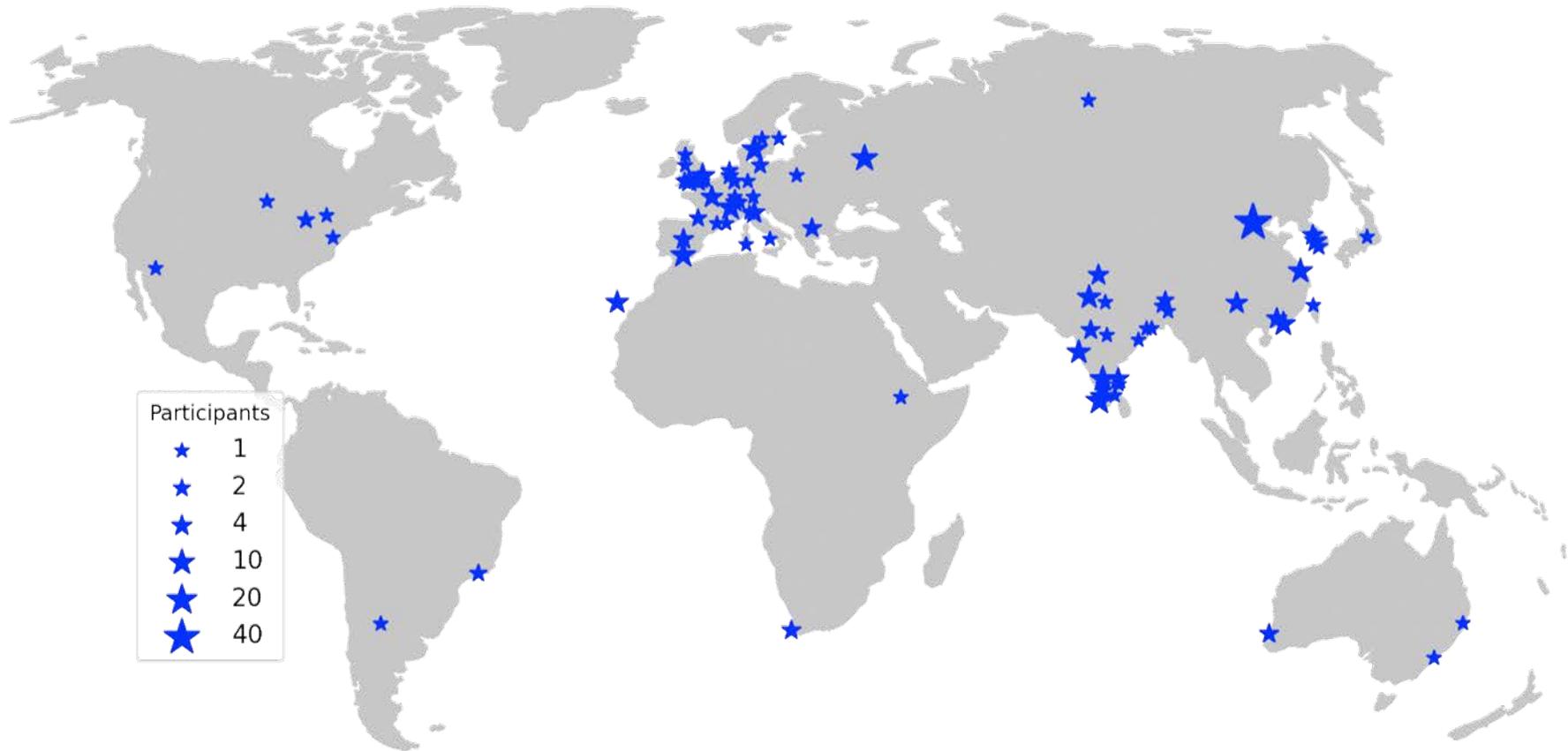
- Illustration of cube (above) is prior to sampling with telescope beam and inclusion of noise
- Almost  $10^6$  simulated neutral hydrogen galaxies and  $10^7$  continuum sources (not shown)
- Expect up to  $10^5$  HI detections with more than  $10^3$  well-resolved



# Science Data Challenge 2

Duration Feb 1<sup>st</sup> – July 31<sup>st</sup>

- 40 Teams with total of 276 participants, from 80 institutes in 23 countries



# And the winner is ...

- About half of the 40 registered teams undertook significant analysis of the SDC2 data products
- 12 teams made final submissions
- Large range of scores
  - Score measures both goodness of fit for true detections and absence of false positives
- Top two teams used non-traditional methods, including internal cross-correlation of sub-teams for winner

Property	Error term	Threshold value
Sky position (RA, Dec) $x, y$	$D_{pos} = \frac{\sqrt{(x-x')^2 + (y-y')^2}}{S'}$	0.3
HI size $S$	$D_{HI\ size} = \frac{ S-S' }{S'}$	0.3
Integrated line flux $F$	$D_{flux} = \frac{ f-f' }{f'}$	0.1
Central frequency $\nu$	$D_{freq} = \frac{ \nu-\nu' }{\nu'}$	0.3
Position angle $\theta$	$D_{PA} =  \theta - \theta' $	10.0
Inclination angle $i$	$D_{incl} =  i - i' $	10.0
Line width $w_{20}$	$D_{line\ width} = \frac{ w_{20}-w_{20}' }{w_{20}'}$	0.3

$$\text{final score} = \sum_{i=1}^{N_{match}} w_i - N_{false}$$



# And the winner is ...

## LEADERBOARD

- About half of the 40 registered teams undertook significant analysis of the SDC2 data products
- 12 teams made final submissions
- Large range of scores
  - Score measures both goodness of fit for true detections and absence of false positives
- Top two teams used non-traditional methods, including internal cross-correlation of sub-teams for winner

The live SDC2 leaderboard below reports the highest score for the full challenge dataset submitted by each team

Position	User	Group	Score	Date
1	minerva	MINERVA	23254.16	2021-07-31T22:08:25.716098
2	forska	FORSKA-Sweden	22489.43	2021-07-14T05:29:44.394263
3	sofia	SoFiA	16822.24	2021-07-27T02:35:21.234327
4	naoc-tianlai	NAOC-Tianlai	14416.02	2021-07-28T12:59:39.209828
5	hi-friends	HI-FRIENDS	13902.62	2021-07-31T20:39:01.416127
6	epfl	EPFL	8515.16	2021-07-31T20:30:40.569408
7	spardha	Spardha	5614.59	2021-07-30T13:54:14.229580
8	starmech	Starmech	2095.65	2021-07-31T15:42:40.105279
9	jlrat	JLRAT	1079.73	2021-07-31T18:13:38.347097
10	coin	Coin	-1.76	2021-07-31T22:48:57.226716
11	hiraxers	HIRAXers	-2.00	2021-07-15T10:55:52.222569
12	shao	SHAO	-471.00	2021-07-31T16:14:46.451245



# SDC2 Next Steps

- Collecting full submission packages (fully documented, portable and customisable SDC2 analysis pipelines) for reproducibility award assessment
- Writing up SDC2 paper
  - Methods employed
  - Relative performance
  - Lessons learned for analysis pipelines
- Post SDC2 analysis and follow-up of HPC Data Centre participation
  - Securing of HPC support for future SDCs
  - Lessons learned for SRC network
- Investigate causes of team attrition



Thank you

*We recognise and acknowledge the  
Indigenous peoples and cultures that have  
traditionally lived on the lands on which  
our facilities are located.*

**SKAO**

[www.skao.int](http://www.skao.int)