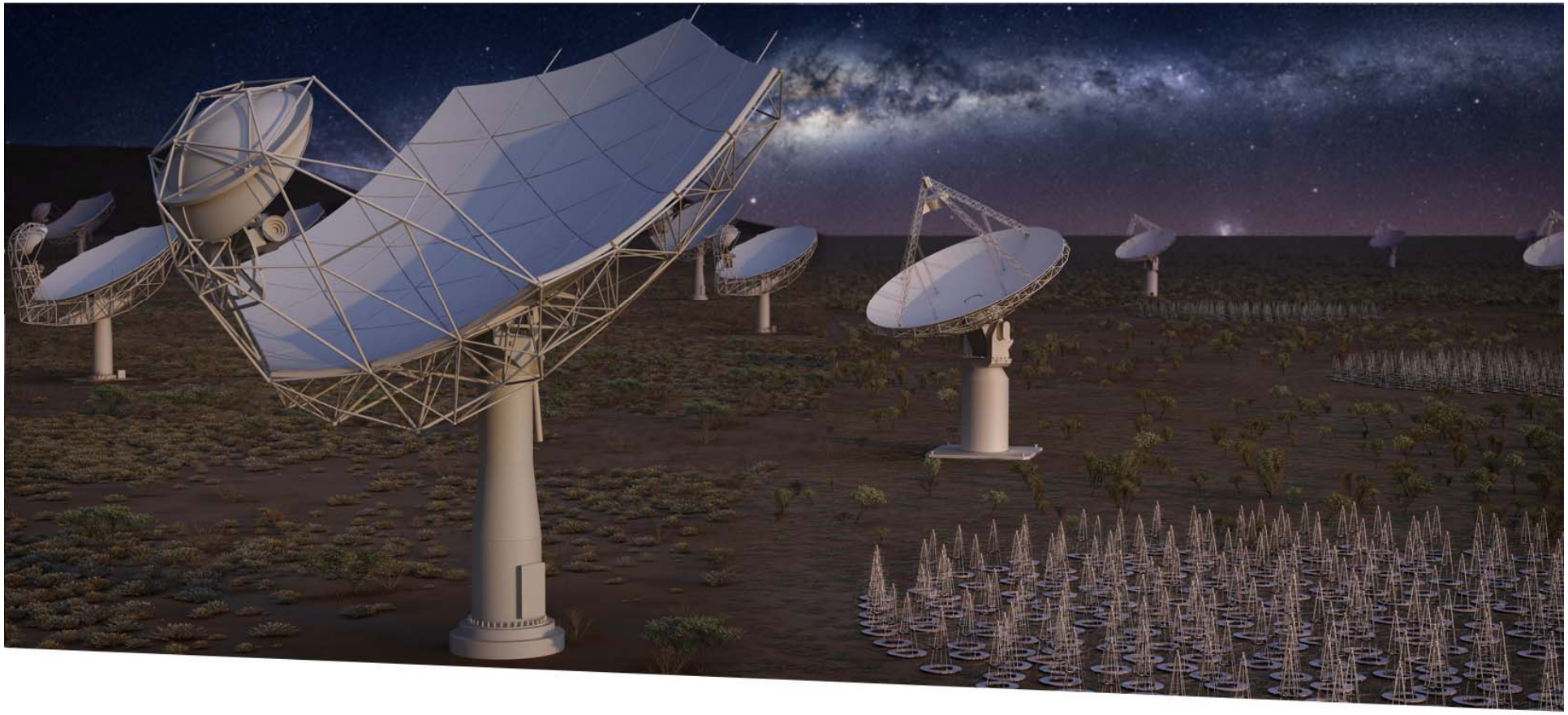
Satellite mega constellations



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

F. Di Vruno

30/01/2020

Agenda

- The SKA
- International protection of radio astronomy frequency bands
- Impact of satellite constellations on SKA
- The future of the radio spectrum for science applications
- Next steps

The SKA Organization

June 2018

July 2018

March 2019

April 2019

Potential Future Members

+.....

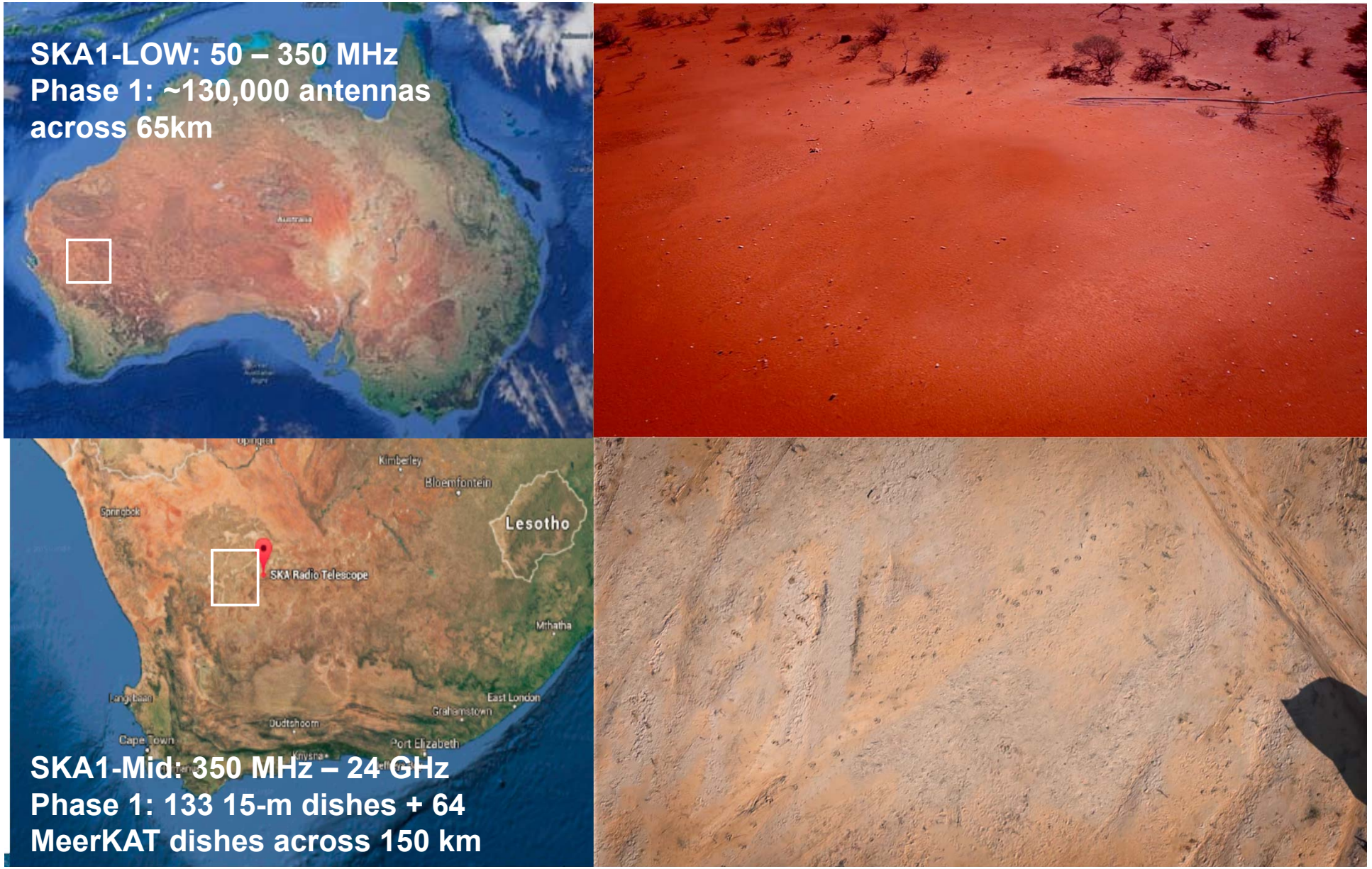
Members of the SKA Organisation
Host Countries: Australia, South Africa, United Kingdom

African Partner Countries

SKA Observatory will be established as an Intergovernmental Organisation in 2020, taking over from the SKA Organisation. It will undertake the construction and operation of the telescope.

As of March 2019, confirmed SKA Observatory members are

SKA: HQ in UK; telescopes in AUS & RSA



SKA1 frequency range and protected radio frequency bands

RQZ protected freq range

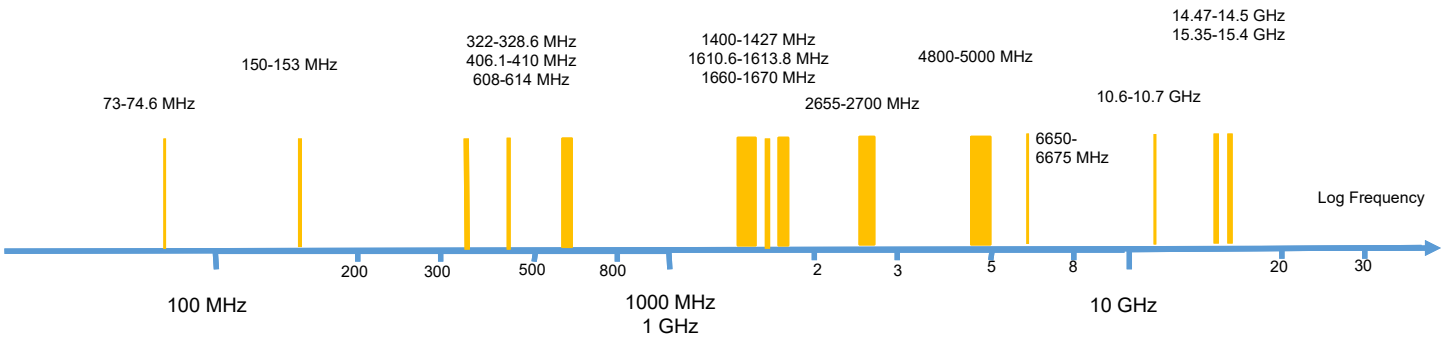
South Africa: 100 MHz - 25.5 GHz
Australia: 70 MHz - 24.5 GHz

SKA Frequency use

SKA LOW
Australia
50 – 350 MHz

SKA MID
South Africa
350 – 15400 MHz

Current ITU-R RAS Allocations



International protection of radio astronomy frequency bands

- The International Telecommunications Union (ITU*) regulates the use of the radio frequency spectrum and satellite orbits.

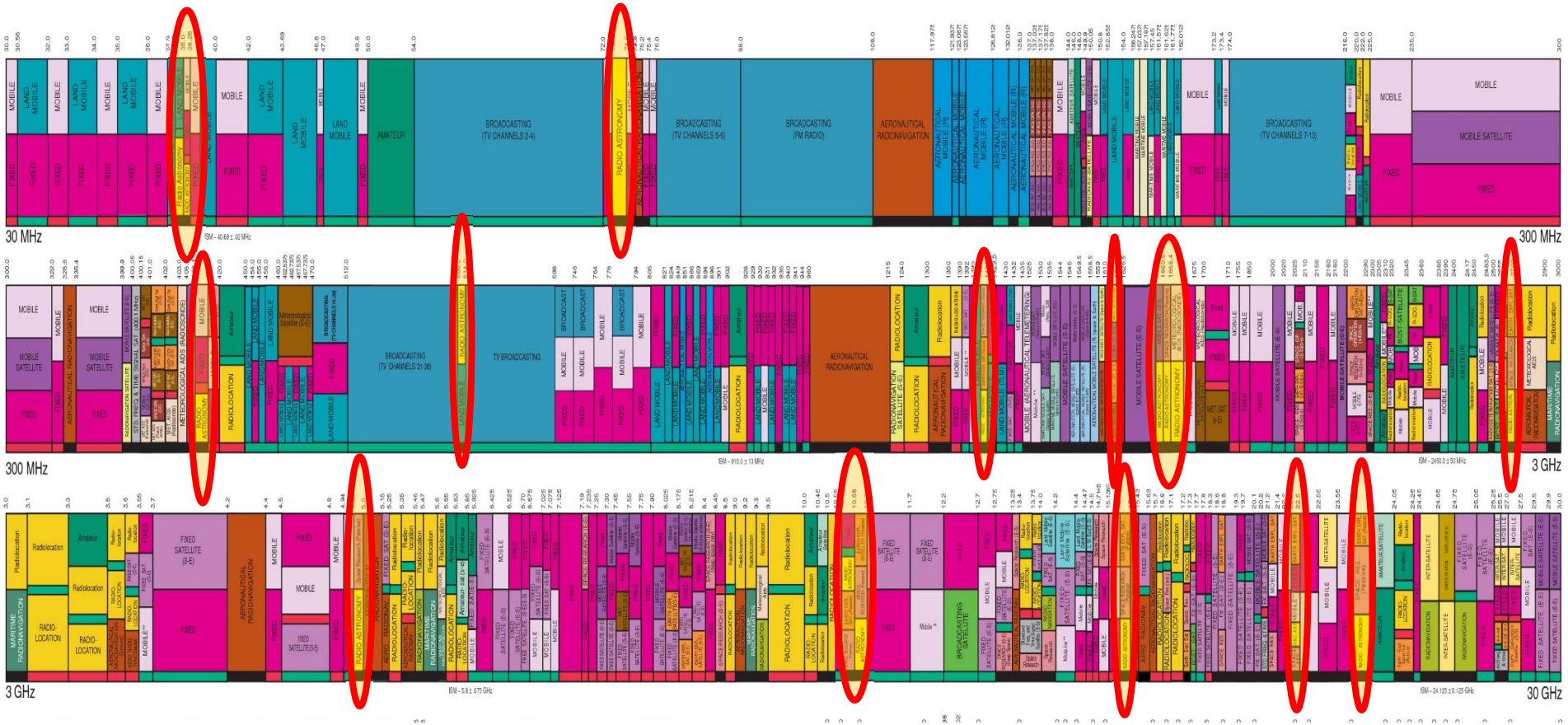
- The ITU has allocated frequency bands for Radio Astronomy use (with primary or secondary status).

- Through its Radio Regulations**, the ITU prevents “harmful interference” between different radio stations.

* ITU is the United Nations specialized agency for information and communications technologies.
**The RR is the international treaty on the utilization of the radio frequency spectrum and satellite orbits.

International protection of radio astronomy frequency bands

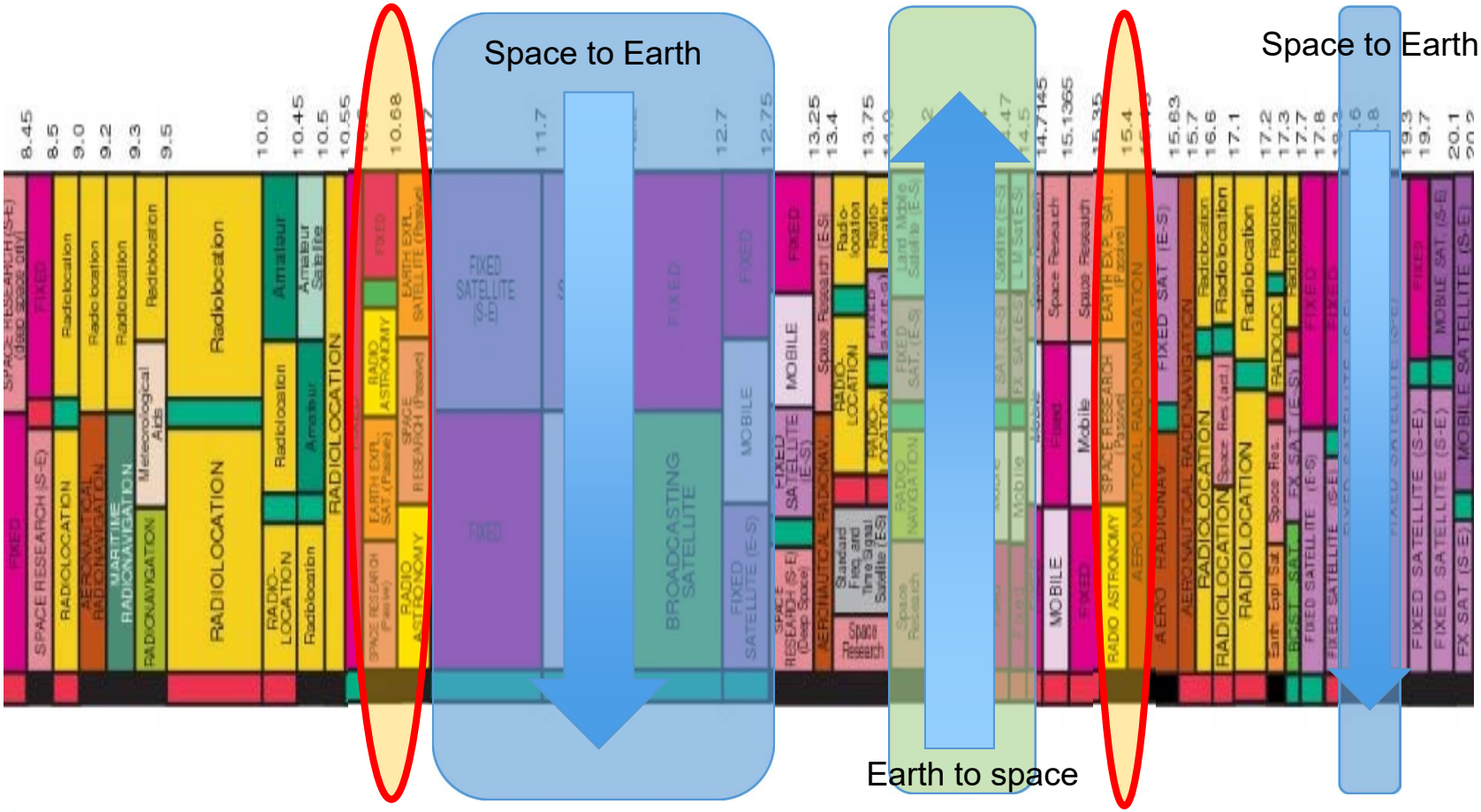
"Sharing" the spectrum



Radio Astronomy Service bands = ~2%

International protection of radio astronomy frequency bands

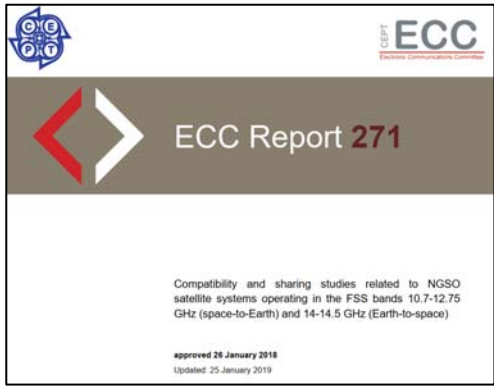
10.6-10.7 GHz & 15.35-15.4 GHz bands: Continuum & VLBI observations



International protection of radio astronomy frequency bands

- A report from CEPT* addresses the protection of the bands 10.6-10.7 GHz and 15.35-15.4 GHz. (OneWeb and SpaceX)

- Results:
  - A strong attenuation in the out of band emissions of the satellites is needed to meet the radio astronomy protection levels in the adjacent radio astronomy band (10.6-10.7 GHz).
  - This translates in the need for operators to **not** transmit in the lowest 250 MHz of the 10.7-12.75 GHz band.
  - Earth-space direction interference into 15.35-15.4 GHz can be mitigated by separation distance (earth station – radio telescope).



*European Conference of Postal and Telecommunications: organization where European countries collaborate to harmonise telecommunication, radio spectrum, and postal regulations.

Satellites impact on SKA

- Modern radio telescopes, like SKA, are inherently broadband and so in most of the frequency range we use, there is no regulatory protection from the ITU.

- SKA sites were specially selected due to their very low radio frequency interference (RFI), furthermore, each national administration manages a Radio Quiet Zone (RQZ) on the sites.

- An RQZ provides a specially managed radio frequency spectrum, no transmitter is allowed within its geographical extent (except when it's use is agreed).

- Unfortunately, RQZ regulations are only applicable at national level, RFI from air and space-borne transmitters is quite difficult to control.

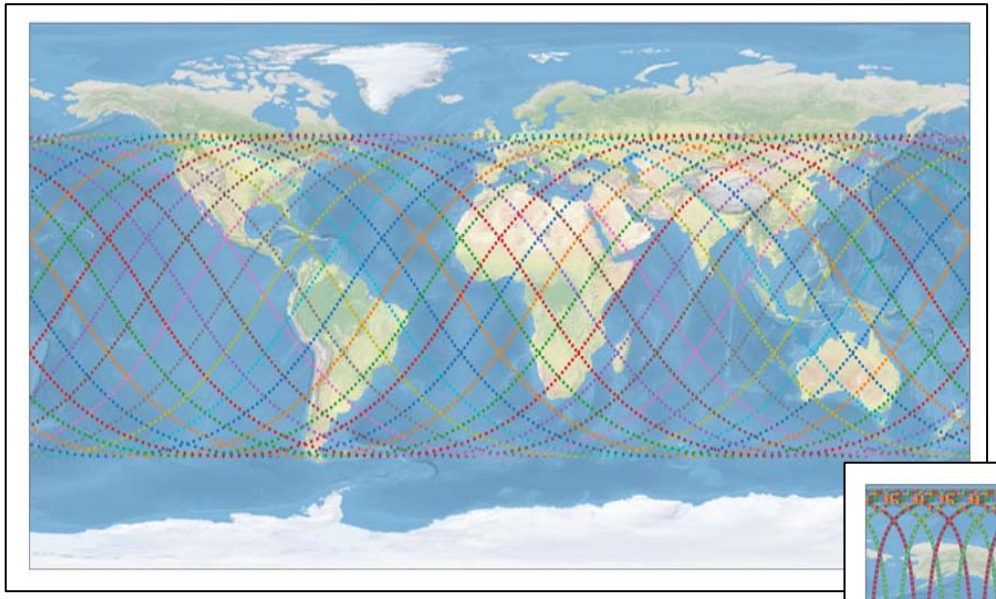
Satellites impact on SKA

- Currently there are ~1300 active satellites in Geo Synchronous Orbit.
- SKA will need to avoid pointing at the geosynchronous belt to prevent high levels of RFI. This means that in a big portion of the sky is not available for radio observations (between 10.7 - 12.75 GHz) even within Radio Quiet Zones.
- With avoidance angles of ~20 degrees, frequencies from 10.7 to 12.75 GHz can be used.
- The new satellite constellations will cover all the globe, meaning that this portion of the radio spectrum might no longer be available in any place on earth at any location in the local sky.
- The possibility of an N-GSO* satellite in the main beam of a SKA antenna (or close to it) increases - this means high received power (by radio astronomy standards).

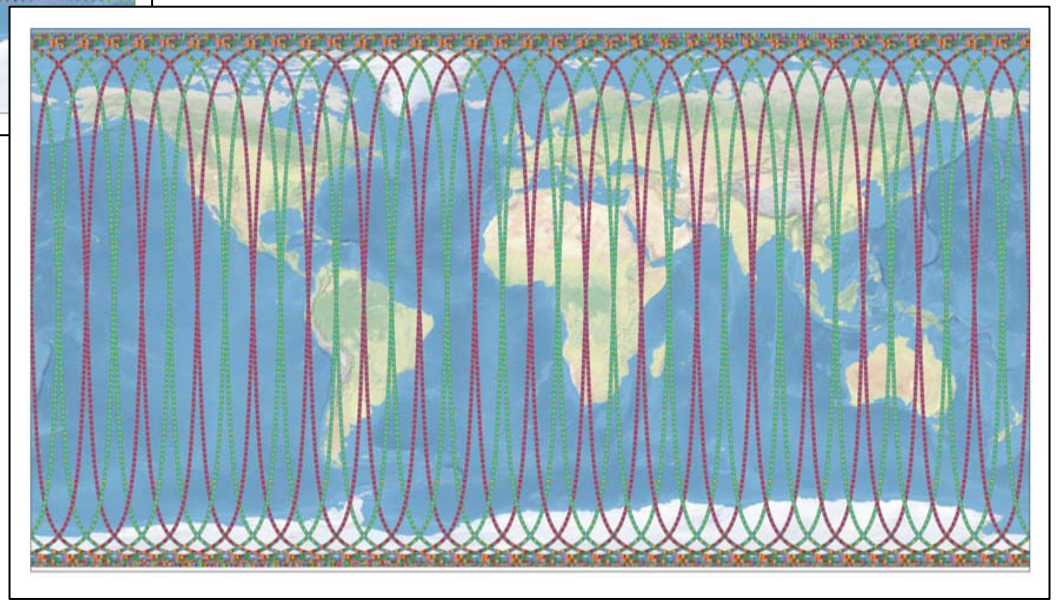
*N-GSO: non geo stationary orbit

Satellites impact on SKA

(ongoing study)



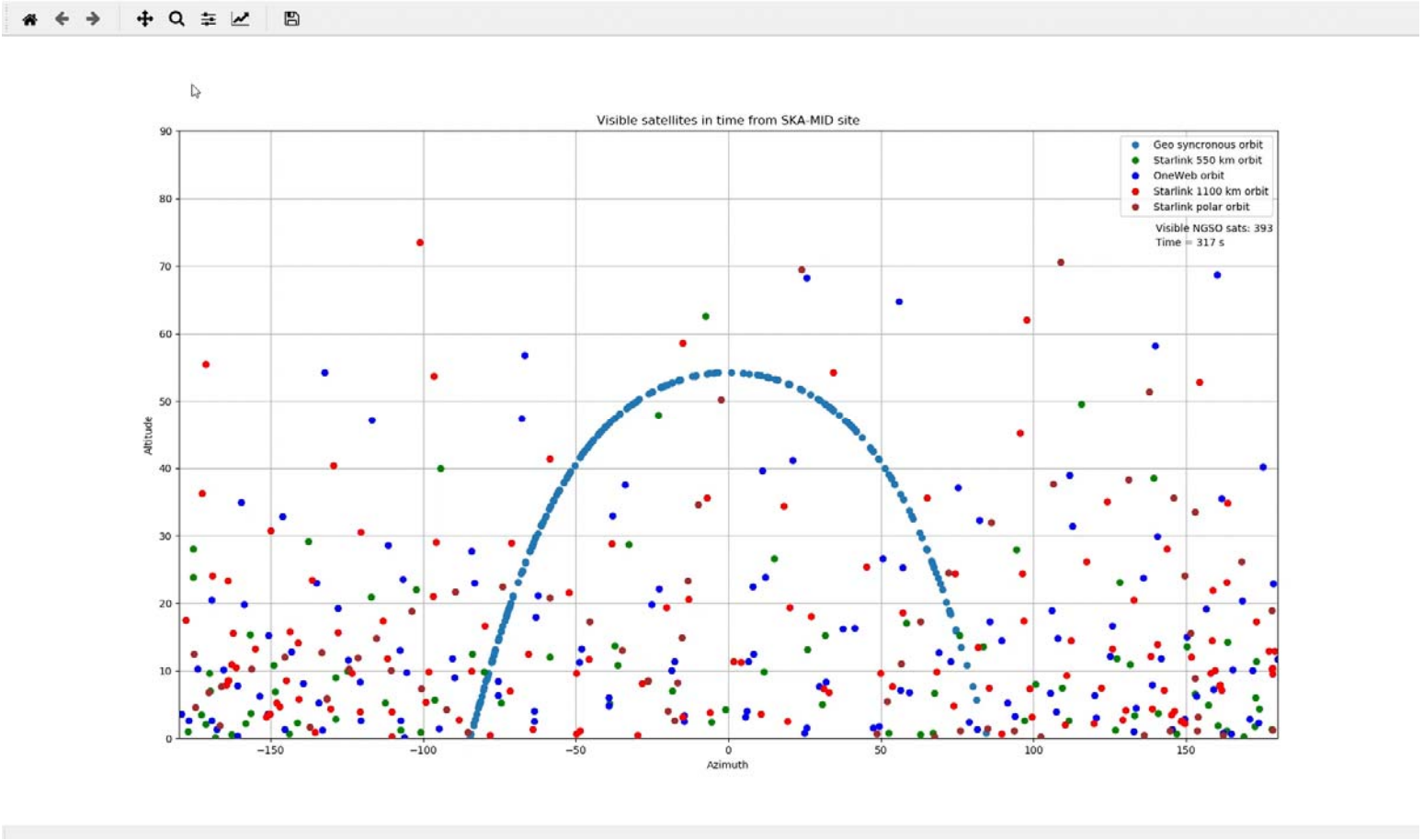
SpaceX (1548 sats @ 550km) superposition, 1hr simulation. Latest amendments to proposed constellations of around 4.400 satellites.



OneWeb (1950 sats) superposition, 1hr simulation

Starlink+OneWeb constellations

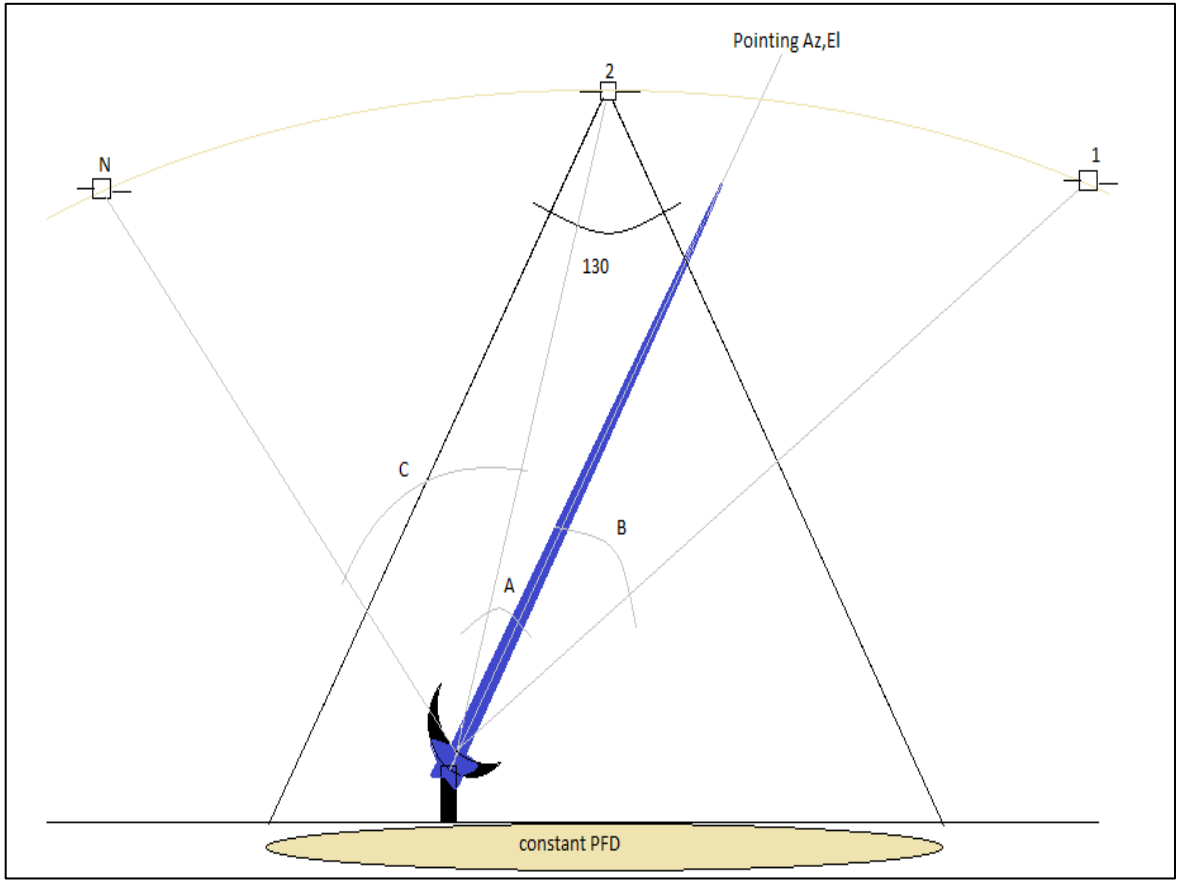
~6000 satellites



Satellites impact on SKA

Assumptions:

- Static pointing
- Satellites moving
- 1-hour duration
- Constant PFD from satellites [dBW/m2]
- Satellite beam modelled.
- Random constellation starting point.
- RAS antenna gain per measurements + ITU-R 1631
- Sky mapped in 25130 points (~1 sq deg)



Impact on SKA (unintentional emissions)

- Apart from intended emissions, electronic components will radiate unintended signals (“Radiated Emissions”).
- Satellites are normally tested under rigorous EMC* military standards, so levels are expected to be controlled.
- If all the new satellite constellations add up to more than 40.000 satellites…
- This means (considering them evenly distributed) that there will be one satellite per every 1 sq degree of sky.
- *With antenna gains in the order of 65-80 dBi is it possible that these radiated emissions reach the “harmful for observations” level?*

*EMC: Electromagnetic Compatibility

Impact on SKA

- Results to be published soon…

The future of the radio spectrum for science applications

- The radio spectrum is only getting more crowded; the protection of the science-services* bands is of vital importance.
- Radio astronomy is continuously investing effort to find a sustainable way of conducting observations in an increasingly crowded spectrum (and sky).
- Could Radio Quiet Zones be protected by satellite operators? An **International RQZ**

*Passive-Service within ITU: Radio Astronomy, Earth Observation

Next steps

- Significant effort is being invested in understanding the potential impact of the new constellations on the SKA.

- SKA is of the view that discussions and agreements with industry are critical to minimize the impact in our observations.