Transients and Science Operations with the SKA

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SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

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Outline

Introduction to the SKA

Transient science with the SKA

SKA Operations for Transient Science

One Observatory

The Square Kilometre Array

Two Telescopes

SKA-LOW

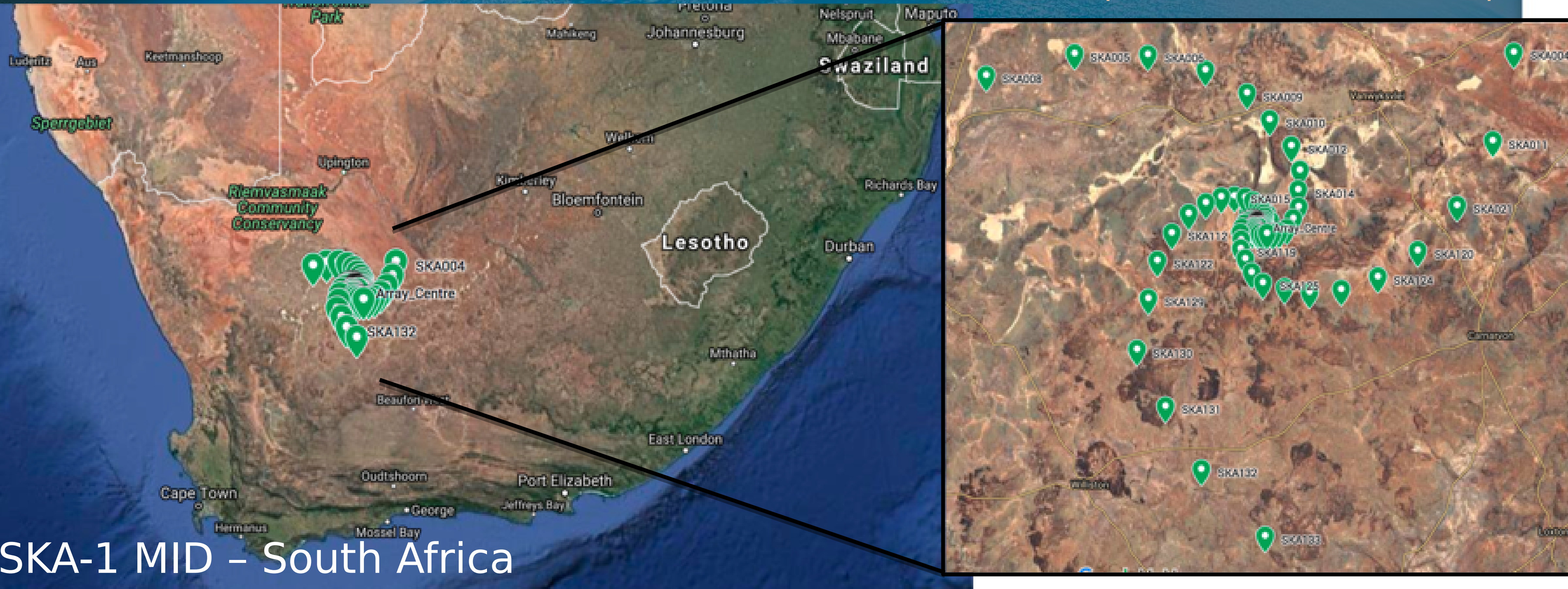
SKA-MID

Three Sites

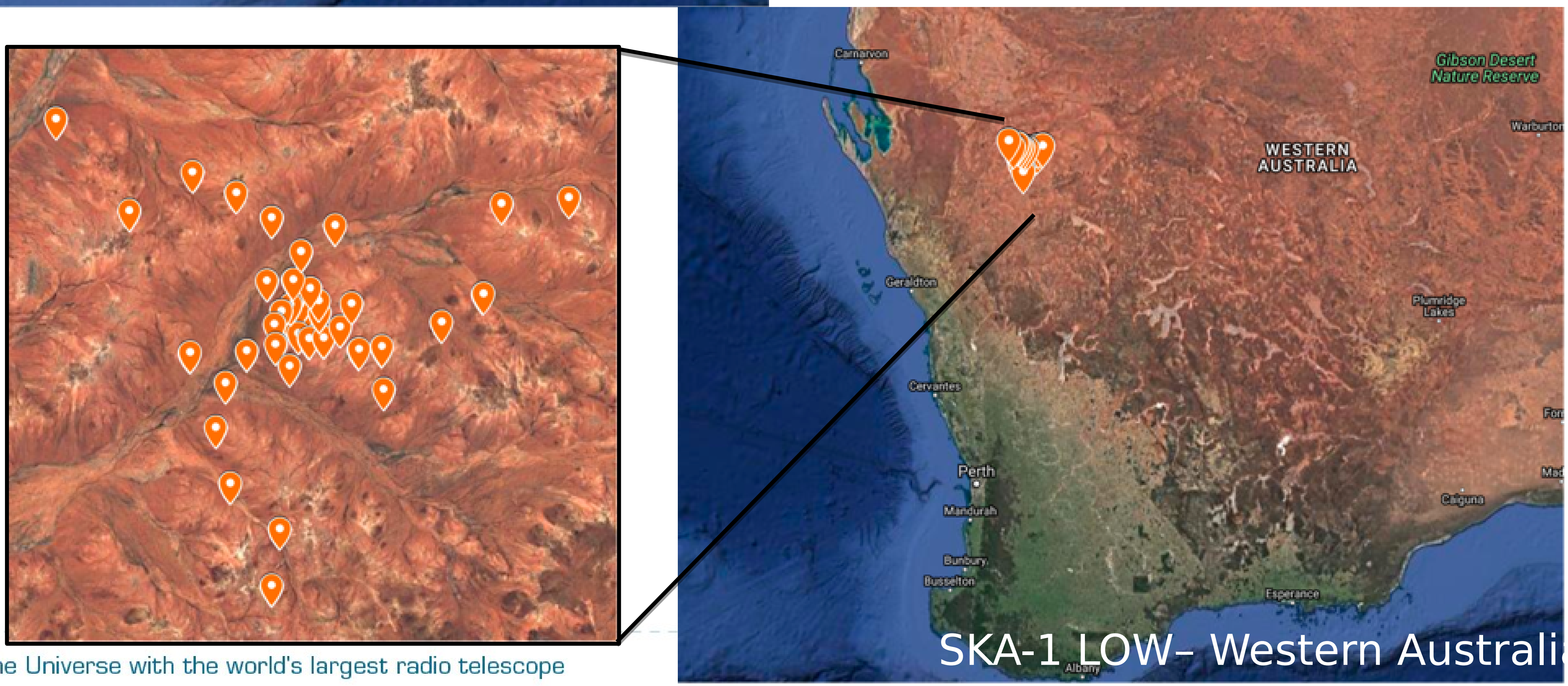
Australia (LOW)

South Africa (MID)

UK (GHQ)



SKA-1 MID – South Africa



SKA-1 LOW– Western Australia

SKA1 MID - Karoo, South Africa

133 SKA1 dishes (15m), 64 MeerKAT (13.5m), core + 3 spiral arms,
150km baseline, 0.35 → 15-GHz covered in 5 bands

SKA1 LOW - Western Australia

131,072 antennas : 512 stations of 256 antennas, core + 3 spiral arms, 65km baselines, 50 → 350-MHz full instantaneous bandwidth

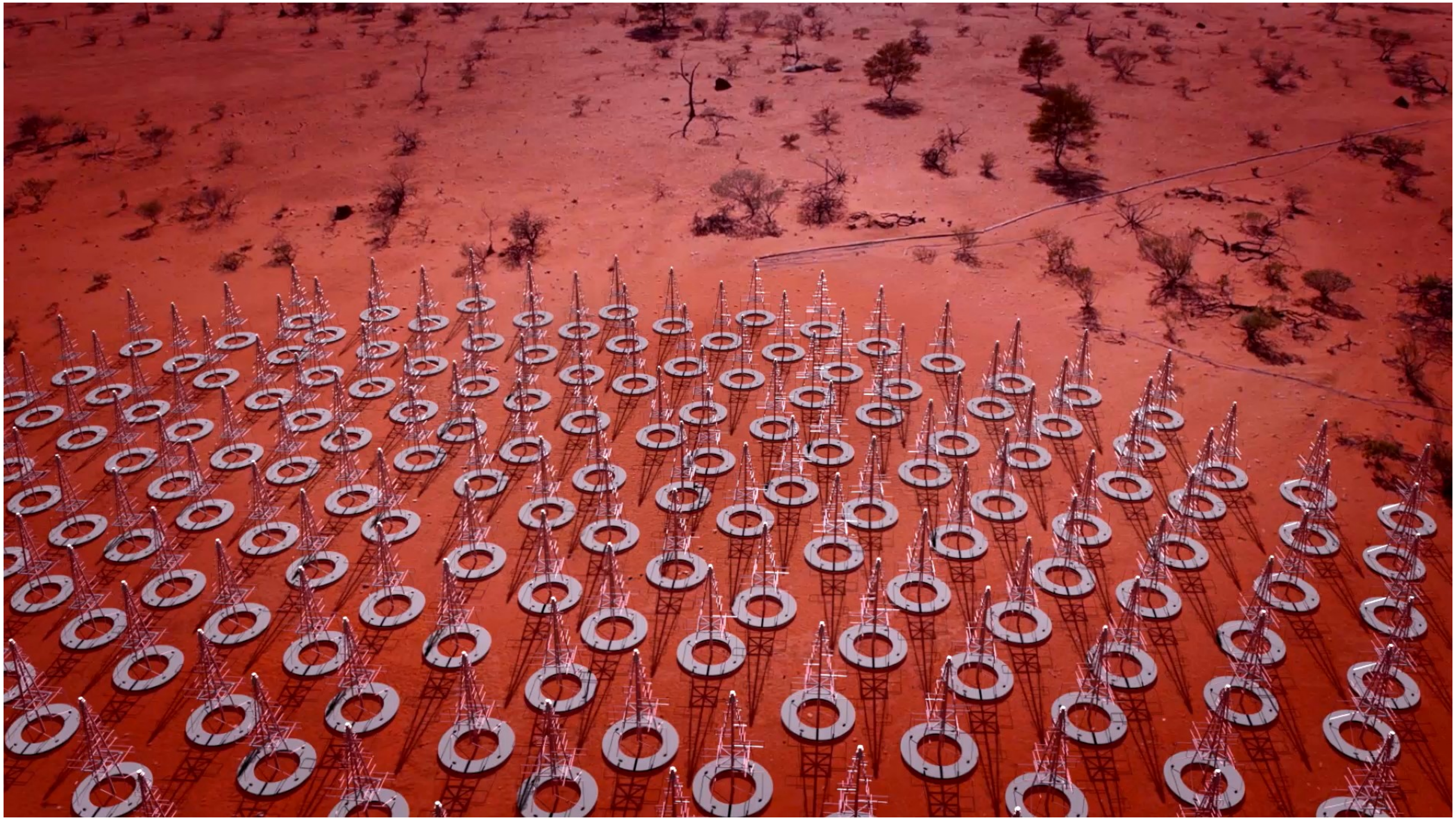
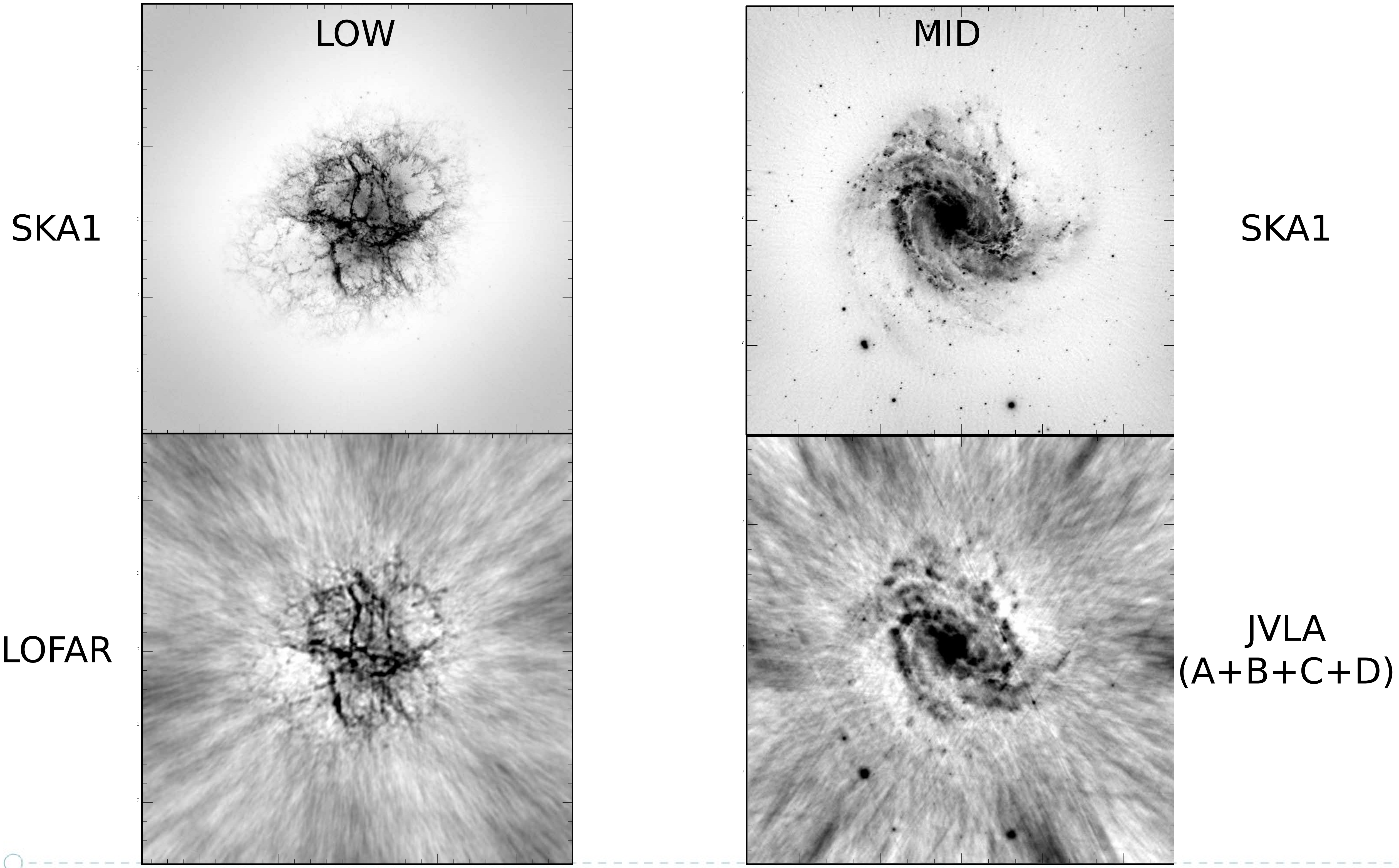
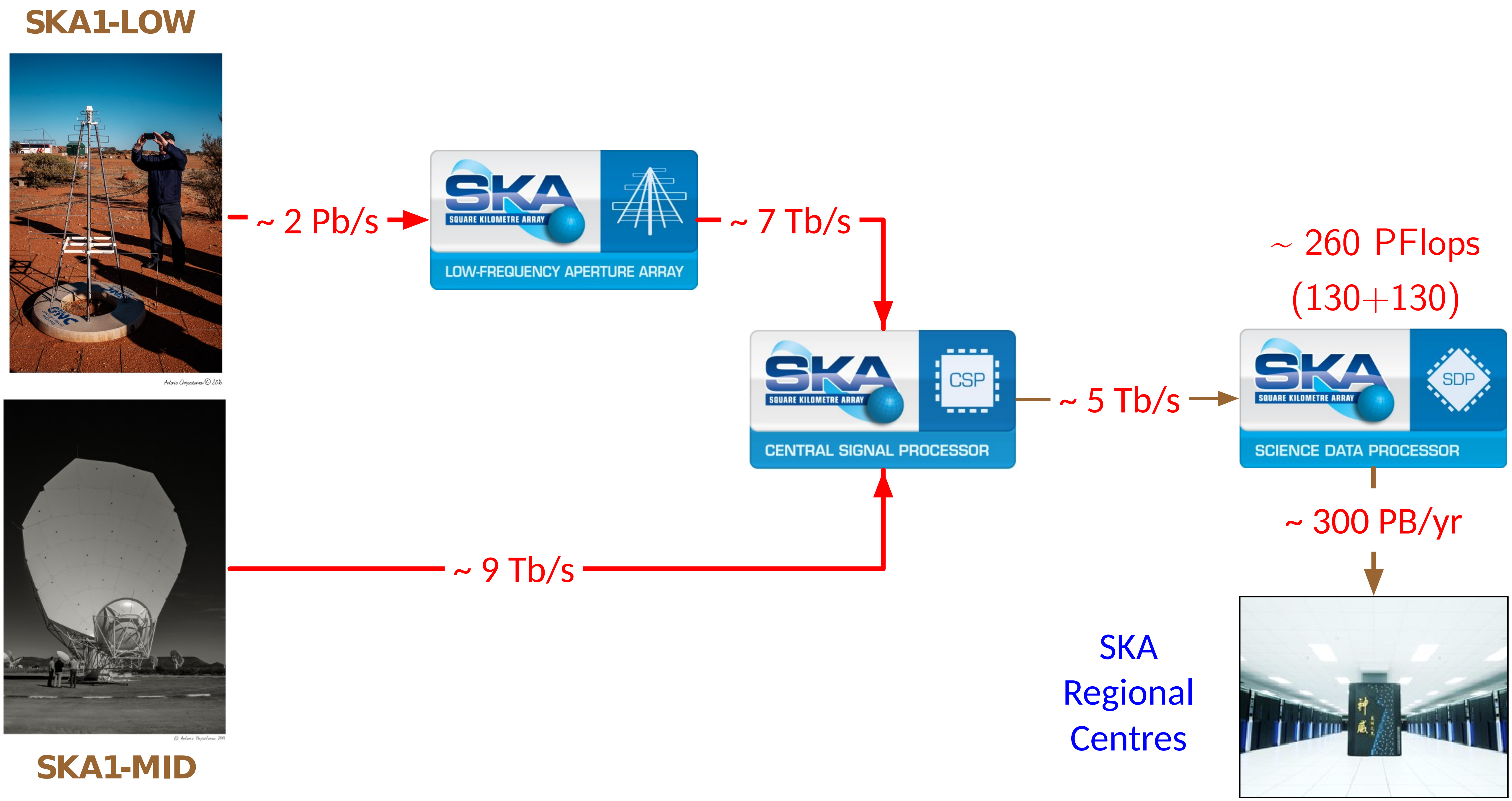


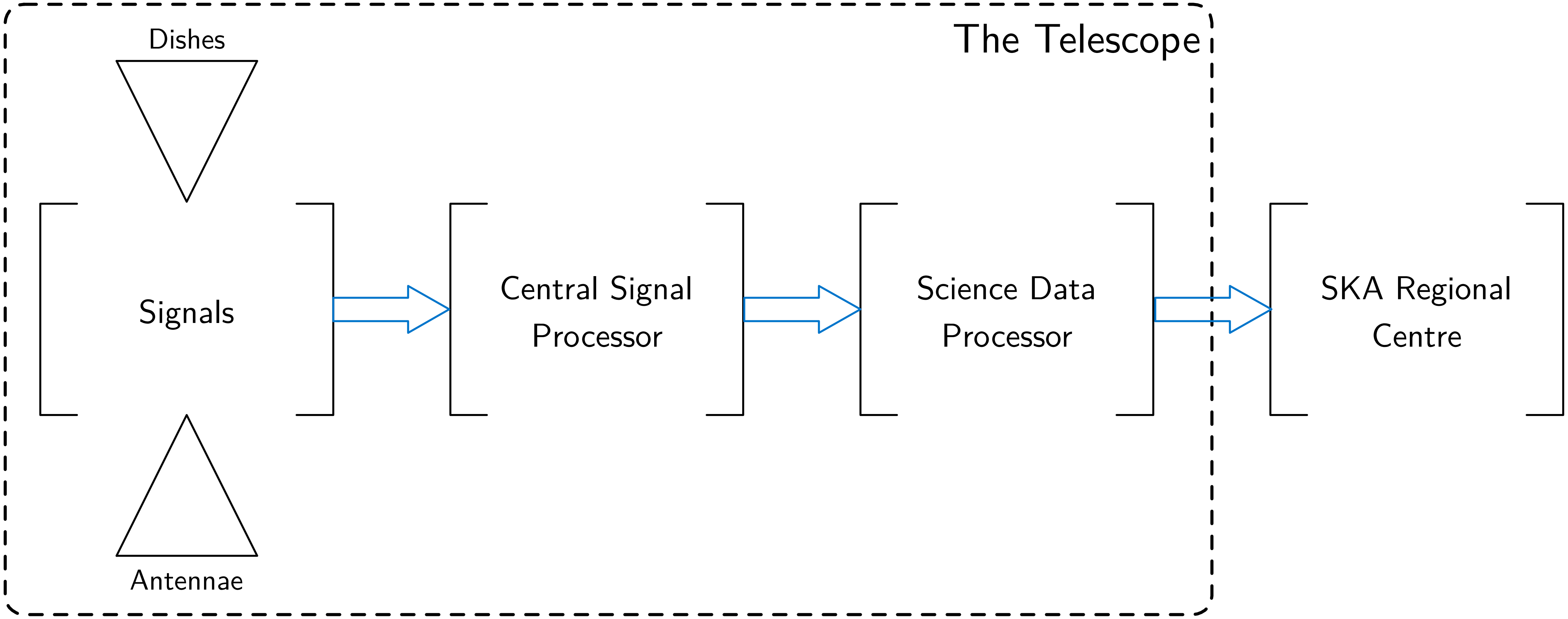
Image fidelity – simulated snapshot images



Data flow


SKA1-LOW
~ 2 Pb/s
SKA SQUARE KILOMETRE ARRAY
LOW-FREQUENCY APERTURE ARRAY
~ 7 Tb/s
SKA SQUARE KILOMETRE ARRAY
CSP
CENTRAL SIGNAL PROCESSOR
~ 5 Tb/s
~ 260 PFlops
(130+130)
SKA SQUARE KILOMETRE ARRAY
SDP
SCIENCE DATA PROCESSOR
~ 300 PB/yr
~ 9 Tb/s
SKA
Regional
Centres
SKA1-MID

Data flow

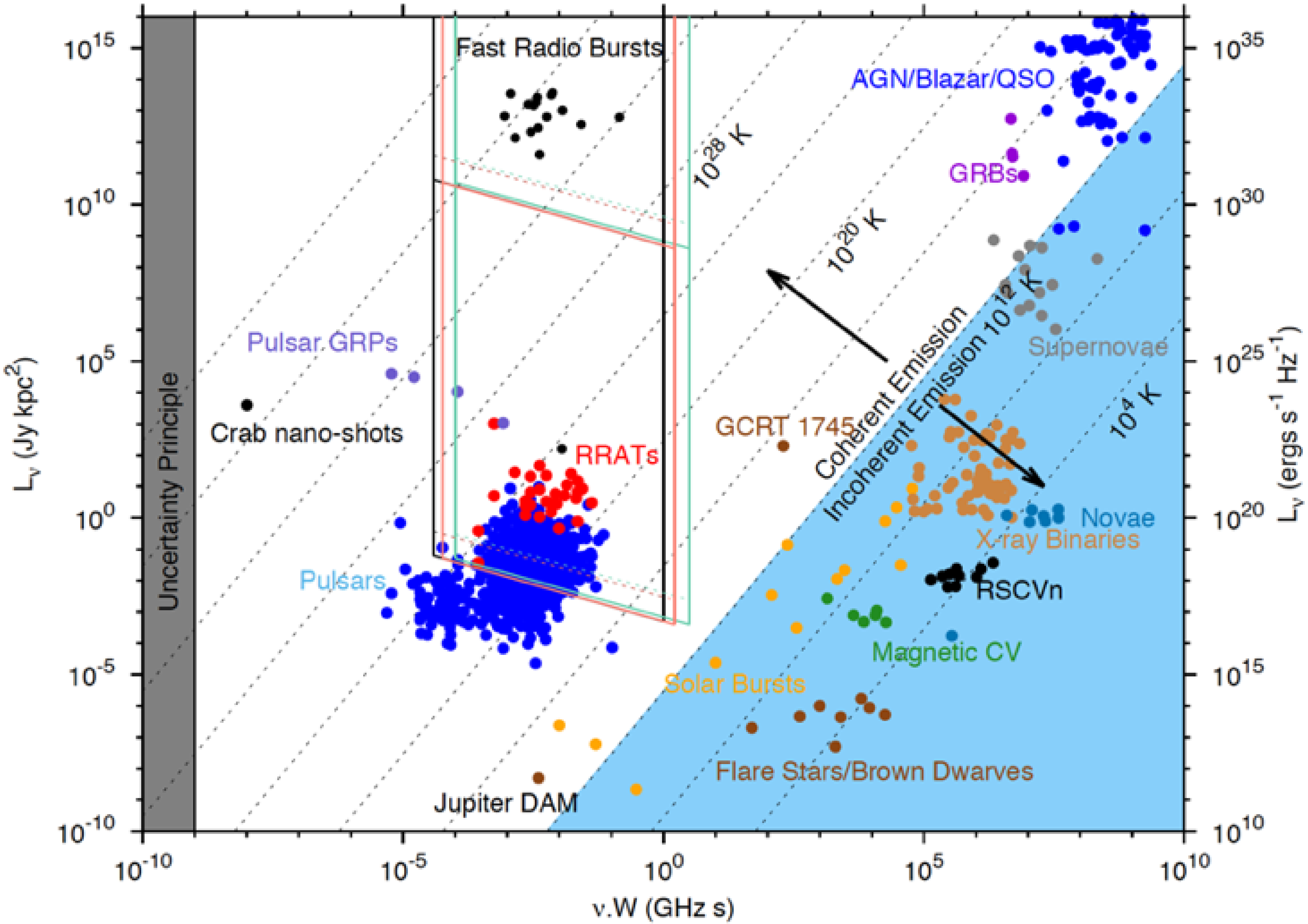


Ordinarily, the science data processor is not considered a part of the telescope

- data reduction should never hamper or obstruct data acquisition
- data rates and volumes emerging from central signal processor are so high that we will not be in a position to store the raw data from the CSP
- it will be cheaper to re-observe than store the raw data indefinitely

The science data processor becomes a schedulable resource of the telescope for observation planning

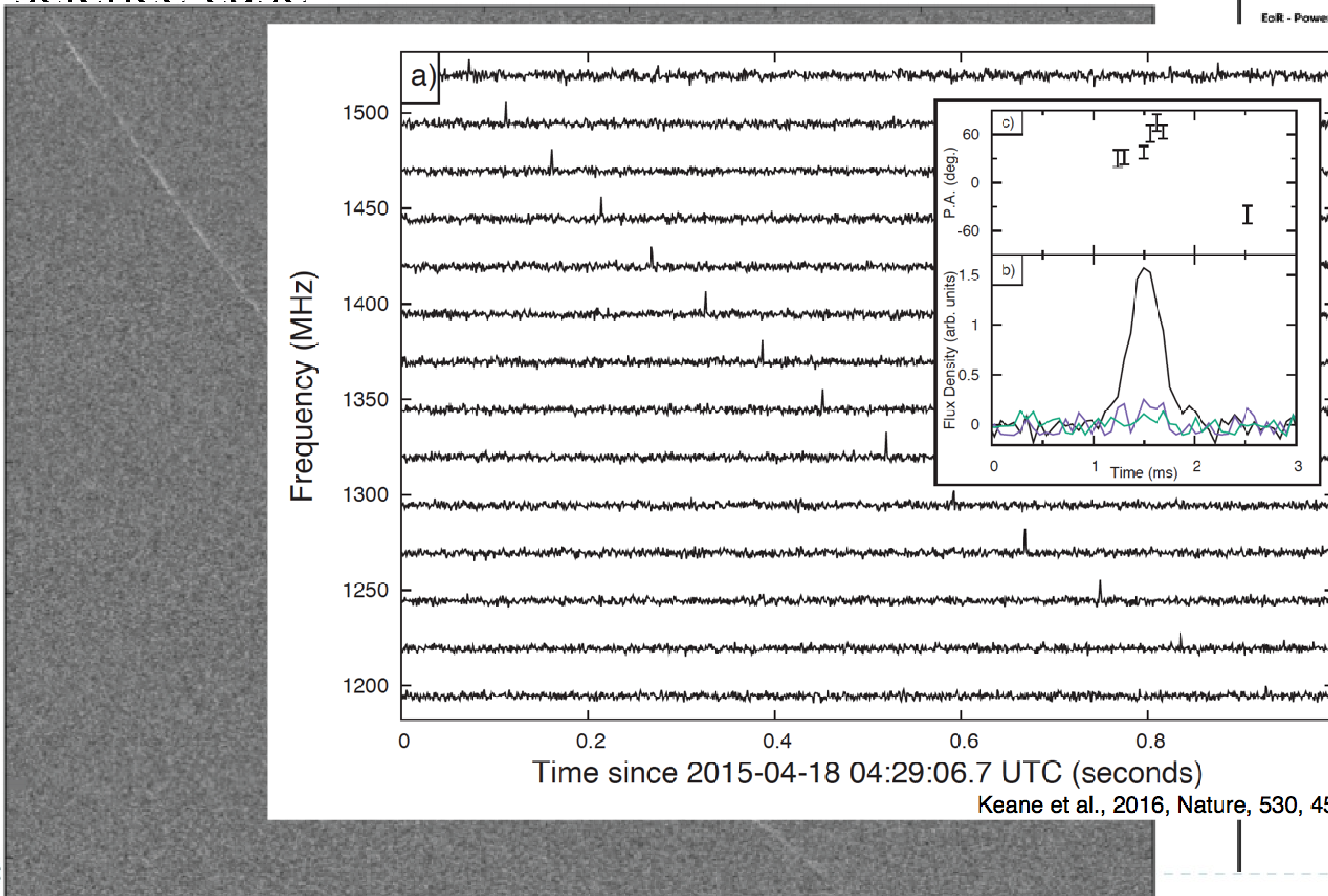
Transients and the SKA



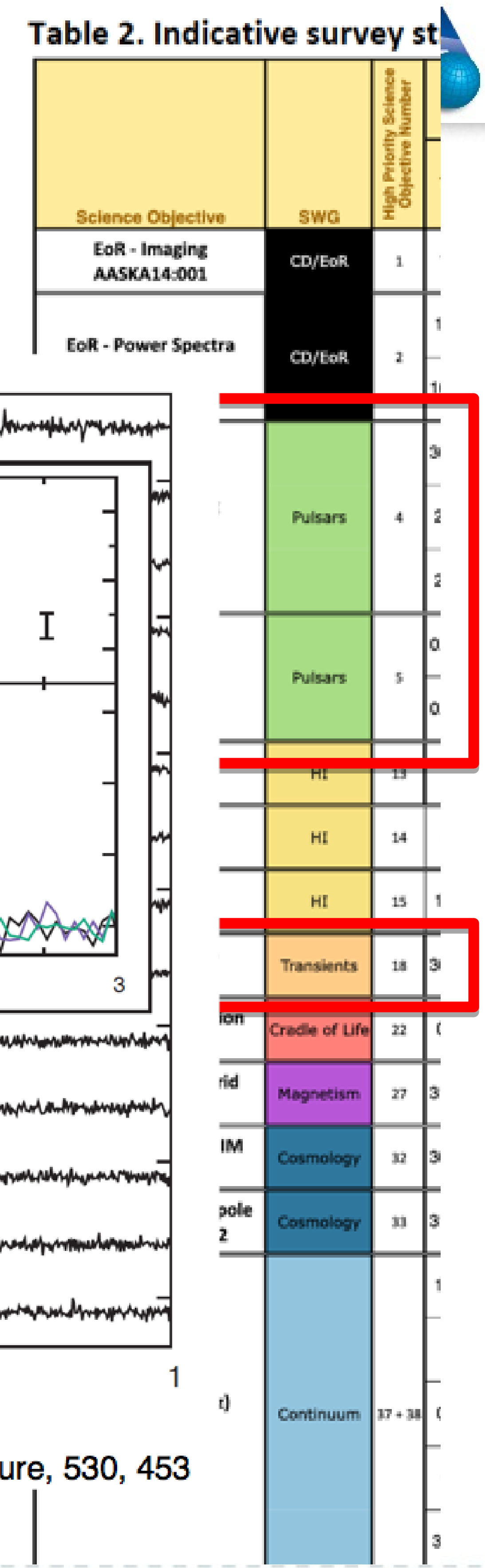
Pietka et al., 2015, MNRAS, 446, 3687(updated with more FRBs)

Transients and the SKA

There is a big emphasis on Pulsars and Transients ir science case



Keane et al., 2016, Nature, 530, 453



Transients and the SKA

There is a big emphasis on Pulsars and Transients in the SKA science case

- High Priority Sci
- Pulsar Searches
- Pulsar Timing
- Transients – FRI
- Precision Astrophysics

Already today, we can do amazing measurements…

Spin parameters:			
Period:	5.757451924362137(2) ms	(Verbiest et al. 2008)	Note: 2 atto seconds uncertainty!
Astrometry:			
Distance:	157(1) pc	(Verbiest et al. 2008)	
Proper motion:			
Orbital parameters:			
Period:			
Projected semi-m			
Eccentricity:			
Masses:			
Masses of neutron stars:	1.33816(2) / 1.24891(2) $M_\odot$	(Kramer et al. in prep.)	
Mass of millisecond pulsar:	1.667(7) $M_\odot$	(Freire et al. 2012)	
Main sequence star companion:	1.029(3) $M_\odot$	(Freire et al. 2012)	
Mass of Jupiter and moons:	9.547921(2) x 10^{-4} $M_\odot$	(Champion et a. 2010)	
Relativistic effects:			
Periastron advance:	4.226598(5) deg/yr	(Weisberg et al. 2010)	
Einstein delay:	4.2992(8) ms	(Weisberg et al. 2010)	
Orbital GW damping:	7.152(8) mm/day	(Kramer et al. in prep)	
Fundamental constants:			
Change in (dG/dt)/G:	$(-0.6 \pm 1.1) \times 10{-}12\ yr^{-1}$	(Zhu et al. 2015)	
Gravitational wave detection:			
Change in relative distance:	100m / 1 lightyear	(EPTA, NANOGrav, PPTA)	

PSR J0437-4715 has a period of:
P = 0.005757451924362137 seconds
± 0.000000000000000002 seconds

But with the SKA…we can do so much more!!

The University of Manchester Jodrell Bank Observatory

Transients and the SKA

There is a big emphasis on Pulsars and Transients in the SKA science case

- High Priority Science Objectives (HPSOs)

- Pulsar Searches
- Pulsar Timing
- Transients – FRBs

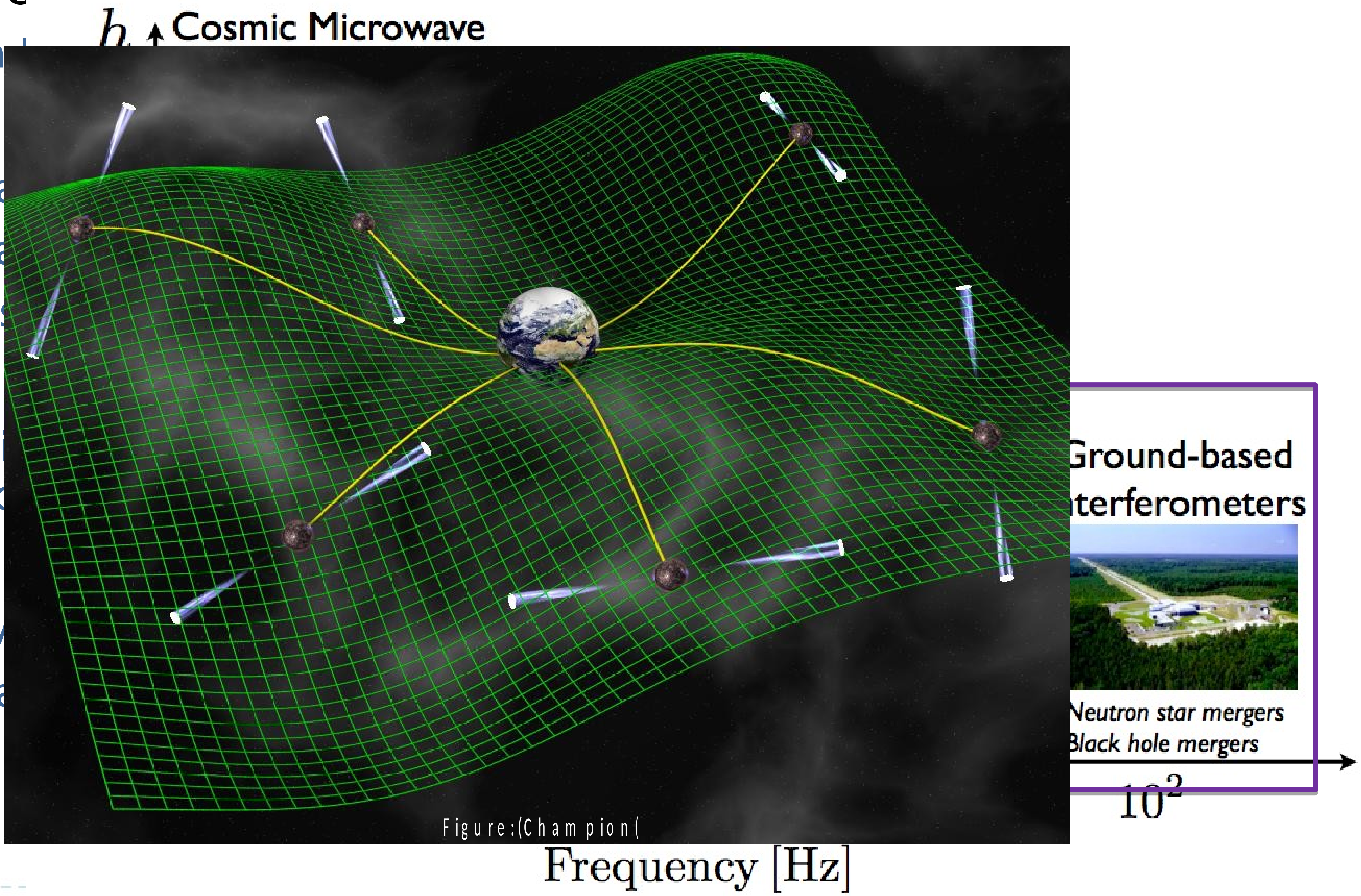
- Precision Astrophysics

- Gravitational Waves

Transients and the SKA

There is a big emphasis on Pulsars and Transients in the SKA science case

- High
- Pulsa
- Pulsa
- Trans
- Prec Astro
- Grav
- Pulsa



SKA Operations & Transients

Search capabilities for Transients

- real-time search capability on both MID and LOW
- 1500 tied array search beams on MID
- 500 tied array search beams on LOW

- can place beams within subarrays
- different subarrays/beams searching different frequency space

- can trade number of beams for bandwidth
- typical observing of 10-mins per pointing

- transient buffers

  20-30 sec for MID

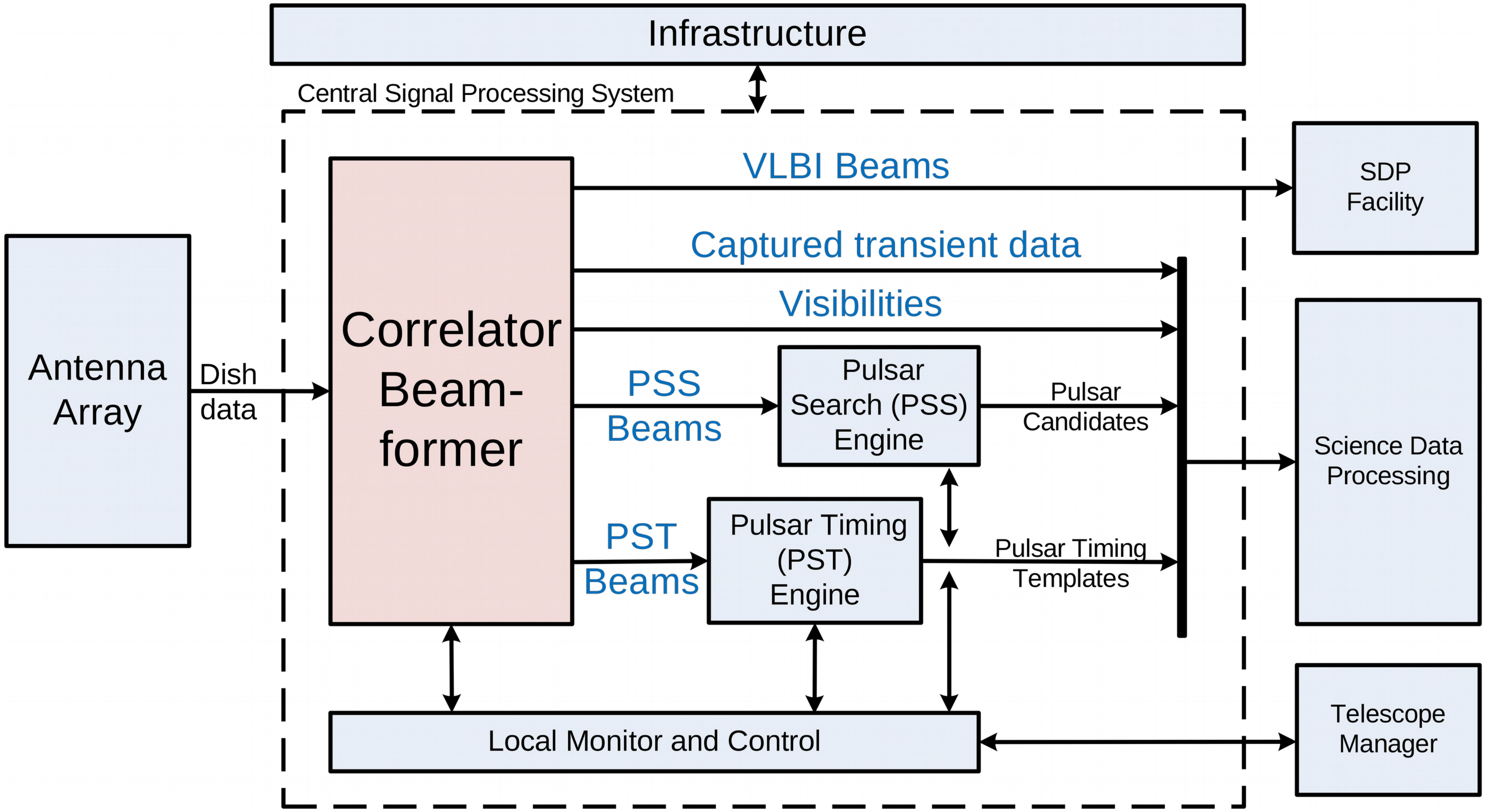
  ~7 mins for LOW

FRB detection rates

Parkes finds ~ 20 FRBs/300 days

Scaling sensitivity & beam
⇒ FRB_{SKA} ~ 1000s FRBs/sky/day

SKA Operations & Transients



Independence of operation of the correlator, beamformer, pulsar search and timing, allows flexibility of operation and commensal operations

- advantage is to have imaging and non-imaging happening concurrently in the same subarray

SKA Operations & Transients

Our aim is to perform Pulsar/Transient search and timing observations in a commensal fashion

- Merriam-Webster definition:

commensality

noun | com·men·sal·i·ty | \ˌkäˌmenˈsalətē\

Popularity: Bottom 40% of words

Definition of COMMENSALITY

plural -es

1 a : the practice of eating together
b : a social group that eats together

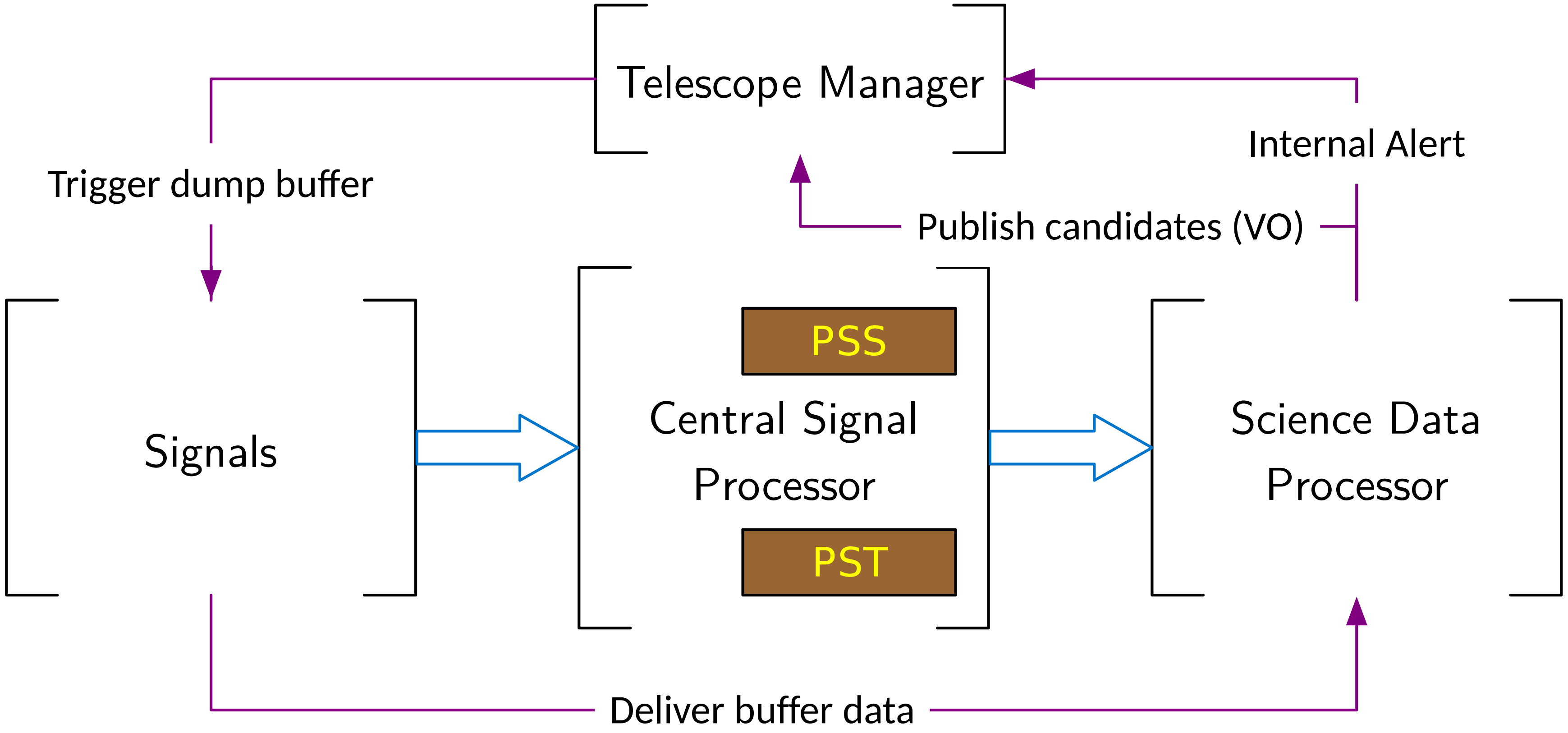
2 : COMMENSALISM

Potentially can perform Pulsar and Transient Search/Timing for 100% of the available time!

- searching with the telescope core while whole telescope is undertaking imaging observations
- then localise positions with arms and core
- follow-up with VLBI (available on MID & LOW)

Publish the most interesting candidates, using VO standards, for follow-up

SKA Operations & Transients



Digitized signal comes into the CSP

- processed by the PSS engine with single-pulse events sent to SDP

SDP makes determination on which events need to be analysed and instructs the Telescope Manager to dump the signal buffer from those events

- buffered data is delivered and processed

“Interesting” candidates are published for follow-up via VO events

- internal and external

How to optimise searches

Spend as much time observing as possible!

- detections are linear with T_{obs}, unsurprisingly!

Maximise the observed sky

- detections are linear with increasing fov
- put lots of beams on the sky

Get the best sensitivity possible (A_{eff}, $\Delta\nu$,…)

- detections increase with log N – log S

Continuous operations

- 24/7/365
- commensality helps → buy a big computer
- get your own telescope

And when you find something interesting….

Conclusions

SKA will generate many 1000s of alert candidates that will be published via VO clients and will be followed up both internally as well as by other facilities

We will also be able to follow up externally generated alerts

- commensality will allow us to respond to alerts more efficiently and (perhaps) to minimise the impact on the active science programme

We are still in the design phase and our consortia will be going through their CDRs in the next year or so

This is a good time for us to learn from the experiences of our multi-messenger colleagues to get our systems, procedures and policies in place and fit-for-purpose

- find me, talk to me!

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