Square Kilometer Array:

The Science & Technology

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Contributions from ICRAR and iVEC.

Outline

- iVEC - Introduction
- My role - Science Visualisation
- Brief history of telescopes and collecting area.
- SKA (Square Kilometer Array)
- ASKAP (Australia SKA Pathfinder)
- West Australia as the site for ASKAP
- Technological challenges.
- iVEC - Delivering Petascale Supercomputing and Enabling eResearch in Australia

iVEC - A Partnership

Partners distributed across Australia

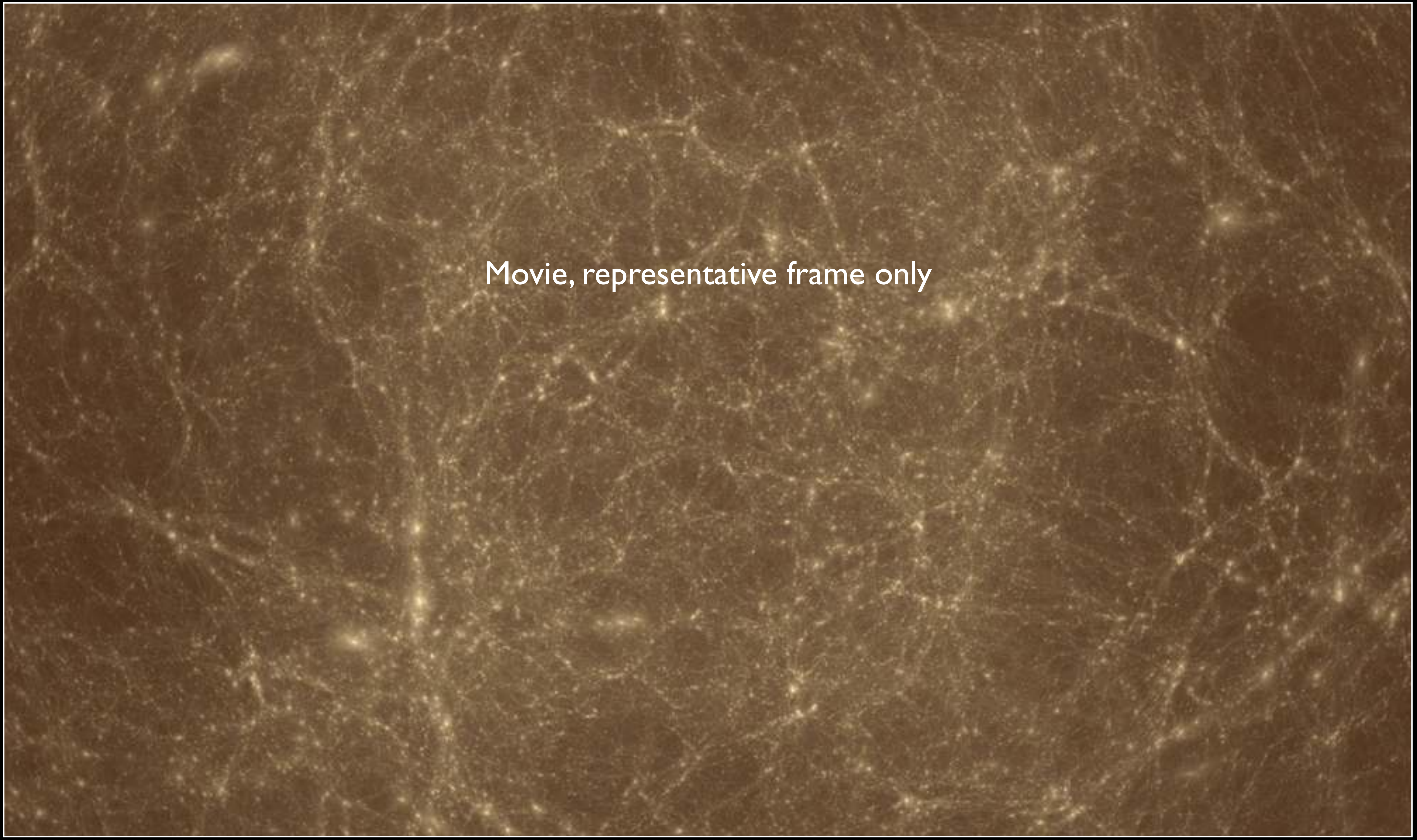
Visualisation

- Using computer graphics, advanced algorithms, and novel displays to bring insight into science data.
- Applies to both observational or simulation data.
- Finds application across almost every area of science today.
- I specialise in novel display technologies to leverage the human visual system.

Stereoscopic

Immersive

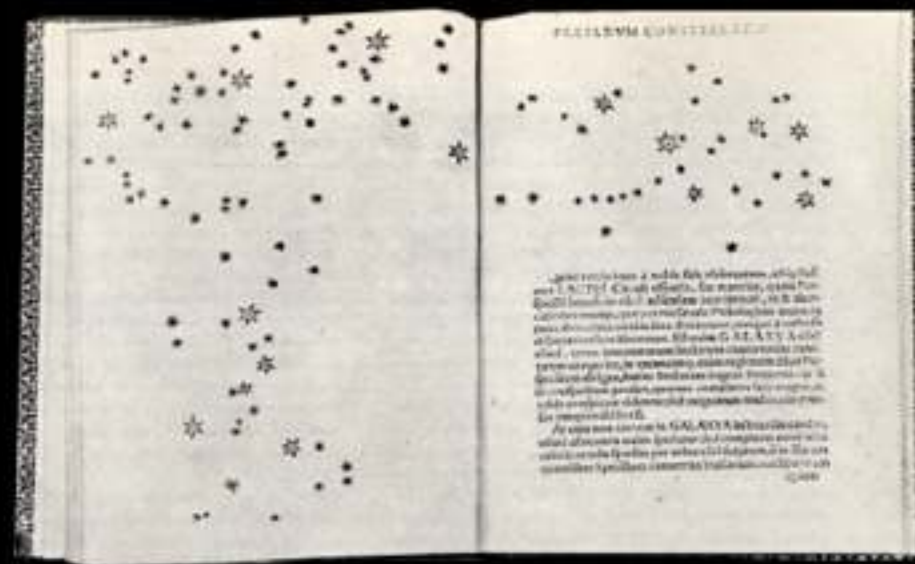
High resolution


Movie, representative frame only


Movie, representative frame only

Introduction to the SKA science: Galileo Galilei (1564-1642)

Galileo's first steps on the journey



New stars

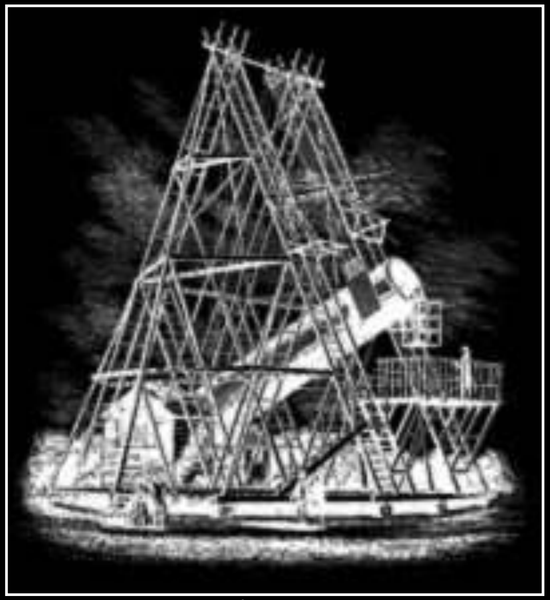
The mountains of the Moon

Why build larger telescopes?

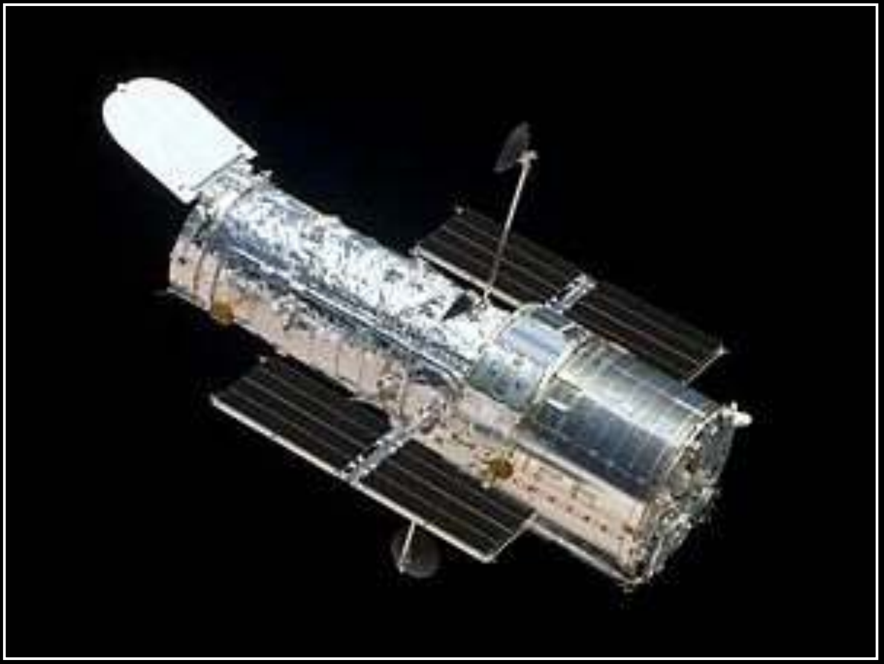
- The light gathering power and ability to resolve detail is proportional to the area of telescope lens.
- So if the lens of the human eye has a radius of about 1/3cm, and the Galileo telescope had a radius of 1 inch so it had a collecting area 20 times that of the human eye.
- Herchel's telescope was 50 inches diameter so had the collecting areas of 45,000 human eyes.
- Diameter of the Hubble space telescope is 2.5m so it has the collecting area of 170,000 human eyes.

Human eye
Radius 1/3cm

Galileo telescope
Radius 1 inch

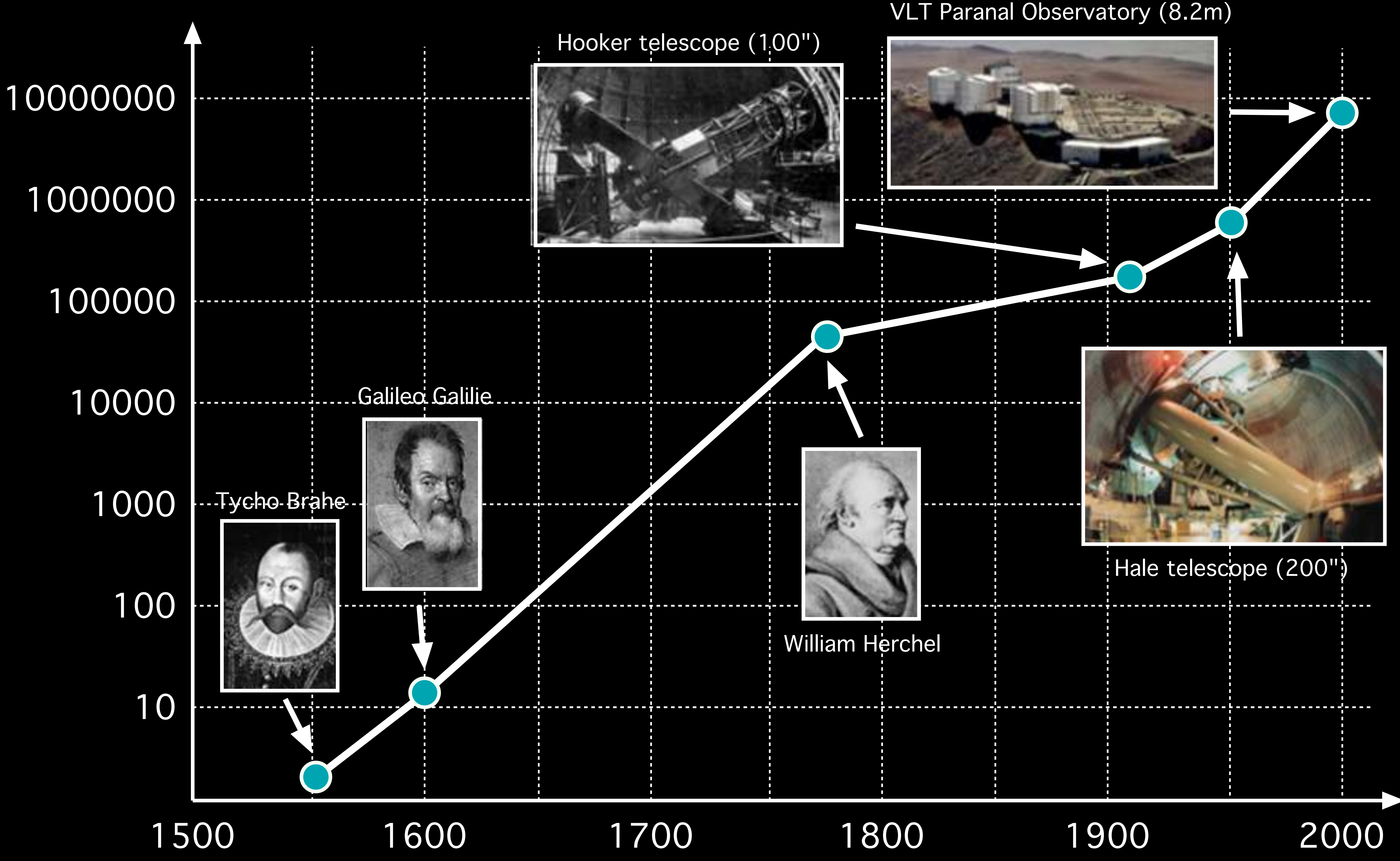


Herchel's telescope
Radius 25 inch

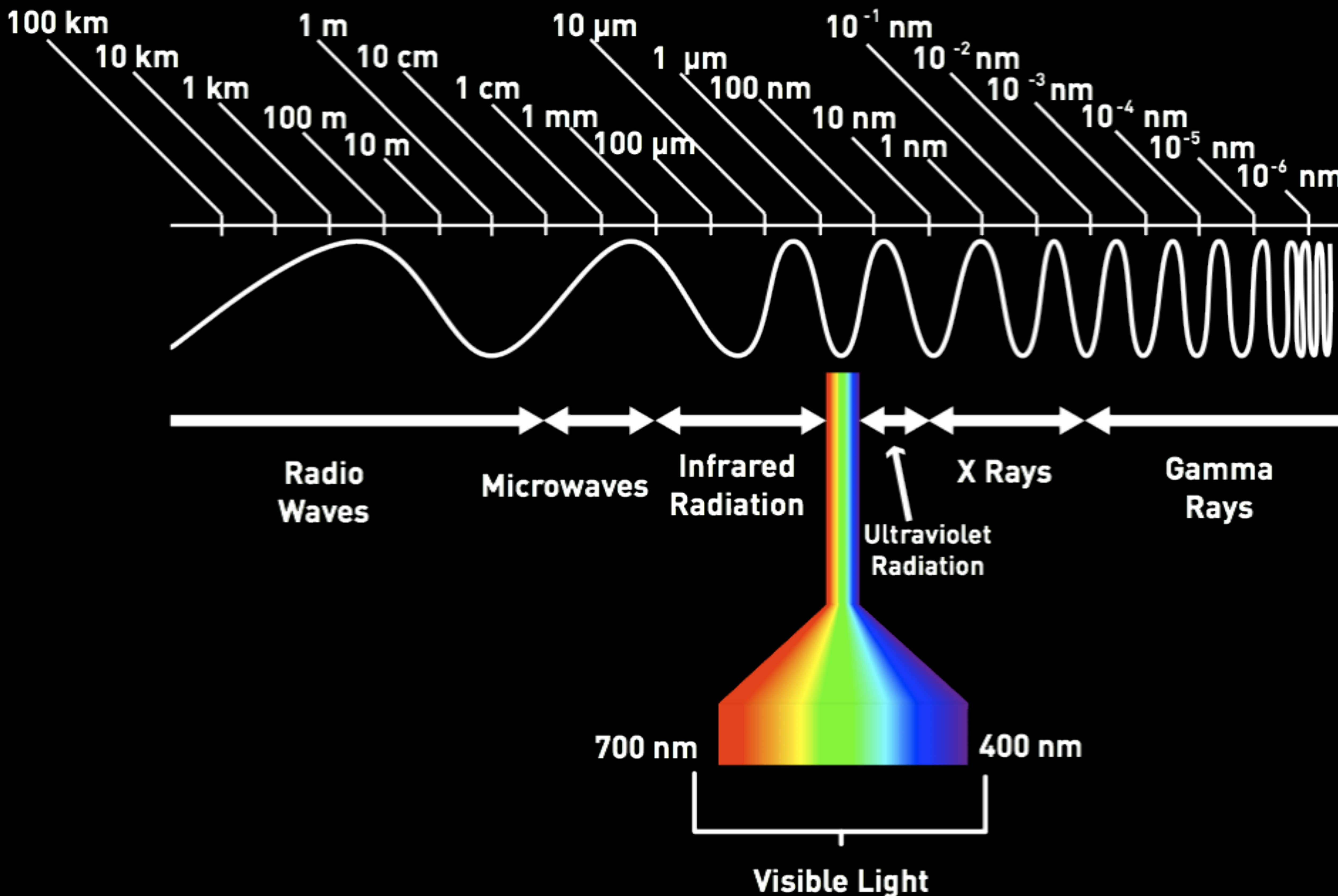


Hubble telescope
Radius 1.25m

Eyes on the sky through history



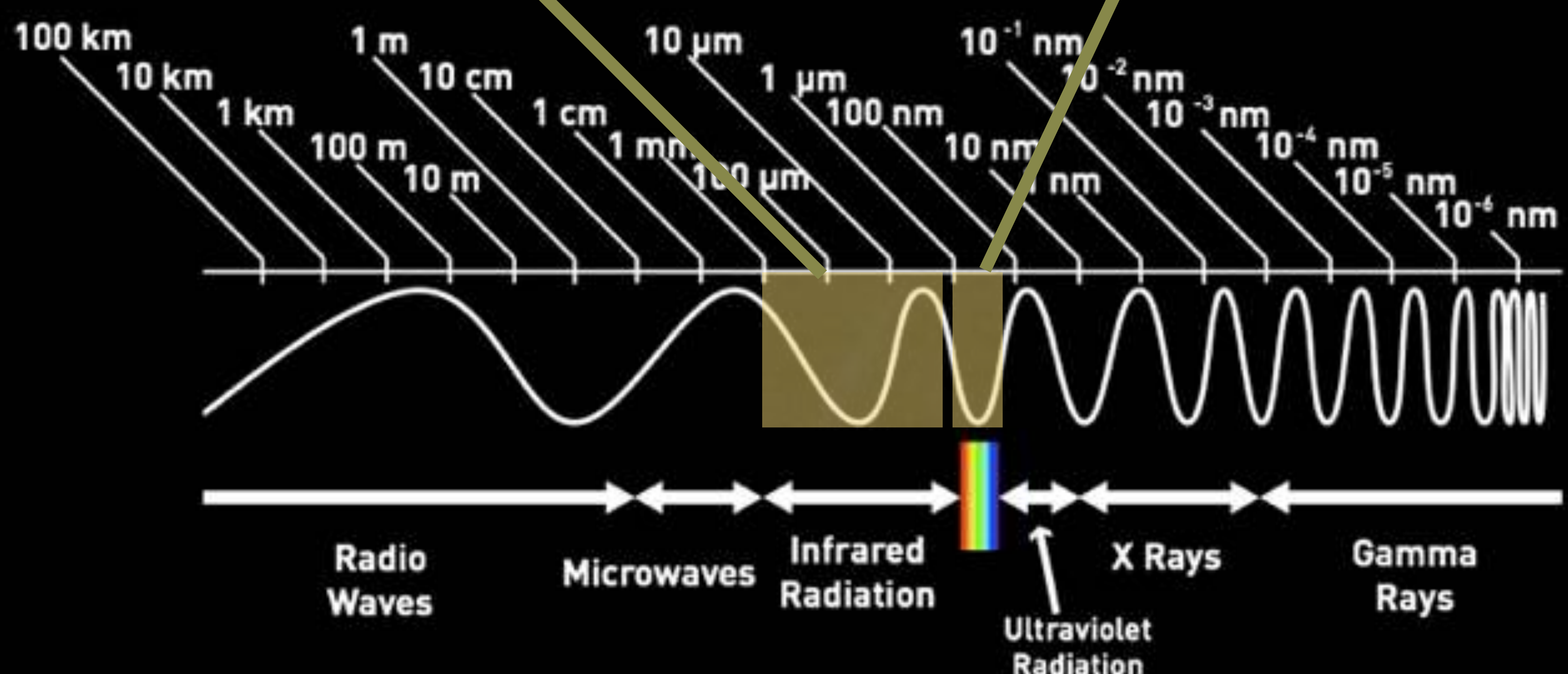
Electromagnetic spectrum



Seeing the world at different wavelengths.

Infrared spectrum

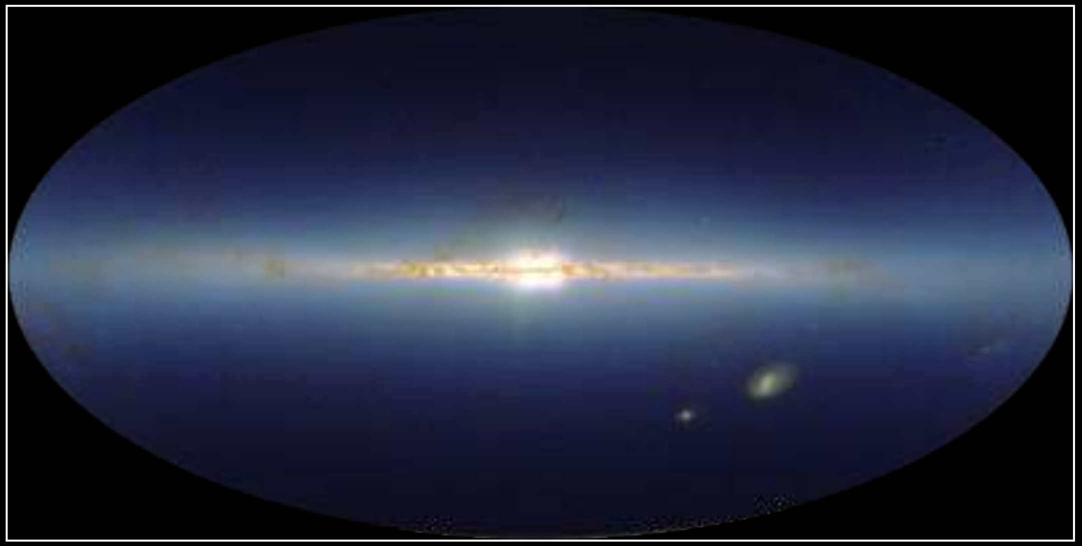
Visible spectrum



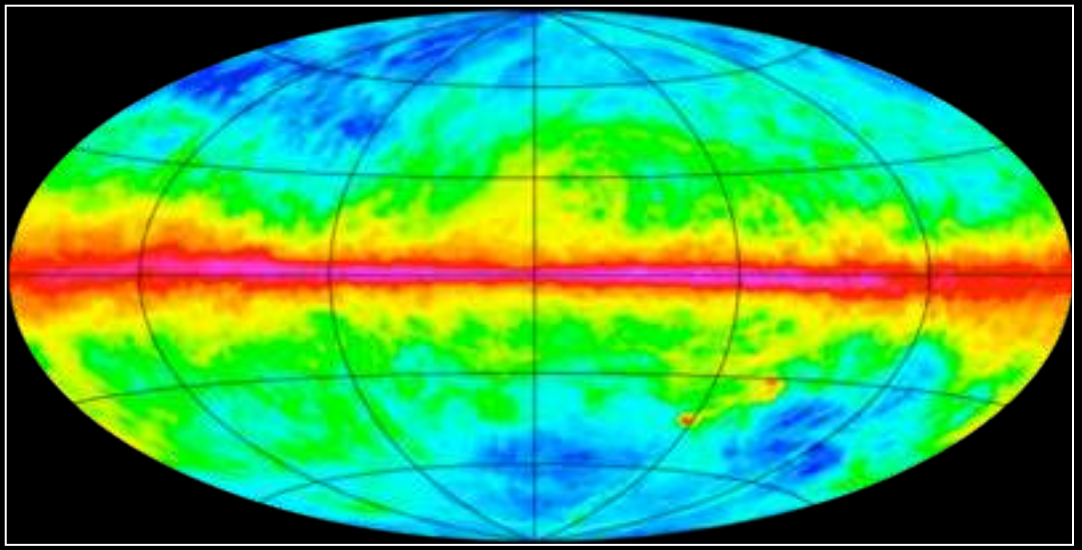
Radio waves

- An optical telescope sees the same part of the electromagnetic spectrum as our eyes.
- Visible light is blocked by dust whereas other parts of the EM spectrum are less affected.
- Things that cannot be seen with an optical telescope can be seen with a radio telescope.
- Radio wavelengths are longer than the wavelength of visible light so dishes need to be larger than optical telescopes.
- In the same way as a lens focuses the collected light on a small sensor, so a dish focus the radio waves on a sensor.

Milky way in visible part of the spectrum

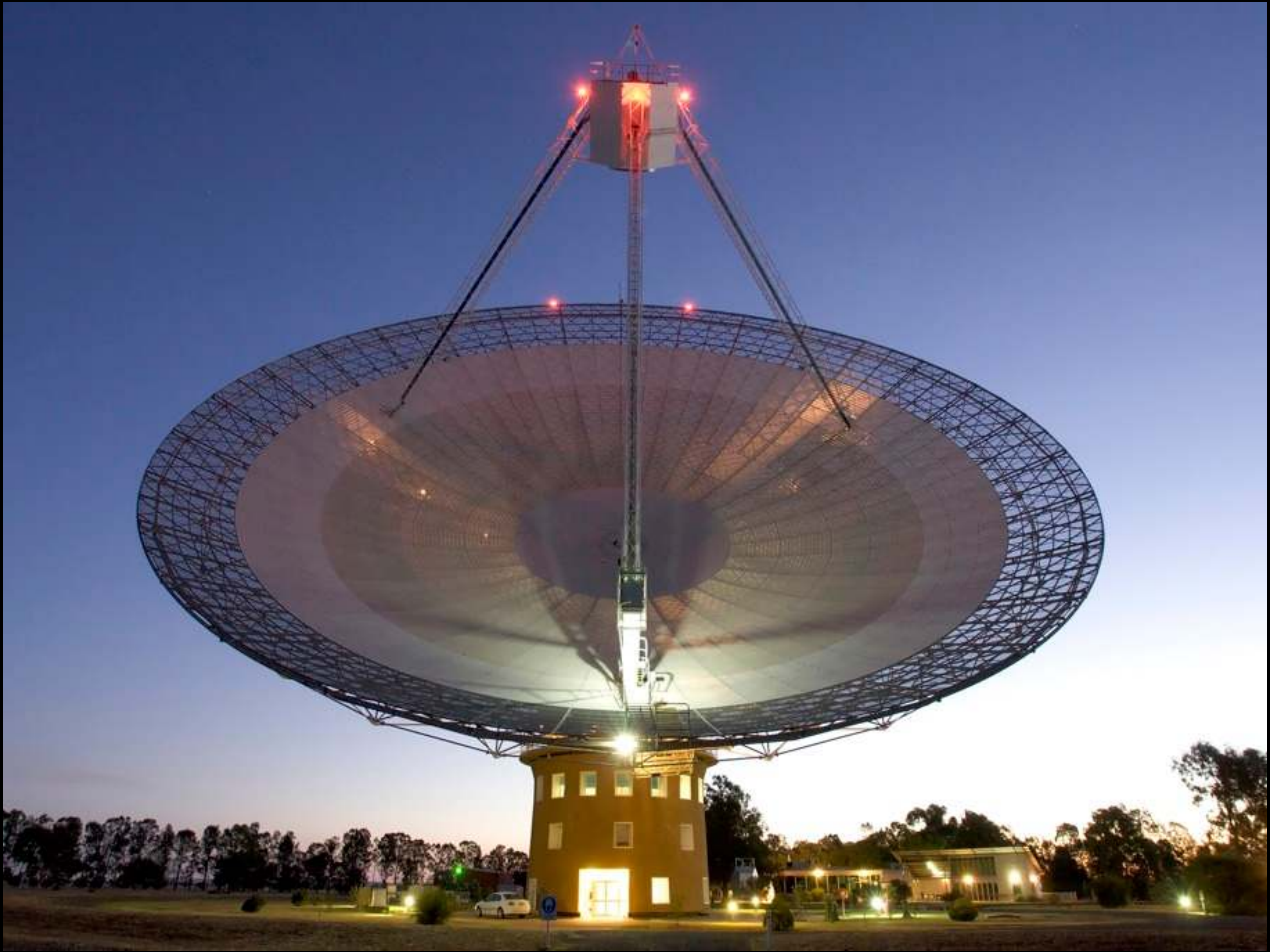


Milky way in infrared part of the spectrum



Milky way in radio wave part of the spectrum

Parkes Radio Telescope (Australia): 1,000 square m



Arecibo Observatory, Puerto Rico: Worlds largest radio telescope

Square Kilometer Array

- The bigger the dish the fainter the objects that can be observed.
- Can't keep building larger and larger dishes. They become too heavy to steer or support themselves.
- If lots of smaller dishes are spread out and the signals combined it can have the same effective size as a large dish. This is called an interferometer.
- Project to build the worlds largest radio telescope by a factor of over 50.
- Will have the collecting area of 1 square kilometer, or 1,000,000 square meters.

Summary

- The SKA will have the effective collecting area of 1km x 1km.

- The SKA will be 50 times more sensitive that the best radio telescope today and be 10,000 times the survey speed.

- The SKA will help answer the following questions:

  - How did the Universe begin?

  - How were the first stars and galaxies formed?

  - Are we alone in the Universe?

  - Was Einstein right in his description of how space, time, and gravity behave?

International project

- The SKA Program is a collaboration between over 70 organisations and institutions in 20 countries - namely Argentina, Australia, Brazil, Canada, China, France, Germany, India, Italy, The Netherlands, New Zealand, Poland, Portugal, Russia, South Africa, South Korea, Spain, Sweden, the United Kingdom and the United States.

Where will it be built?

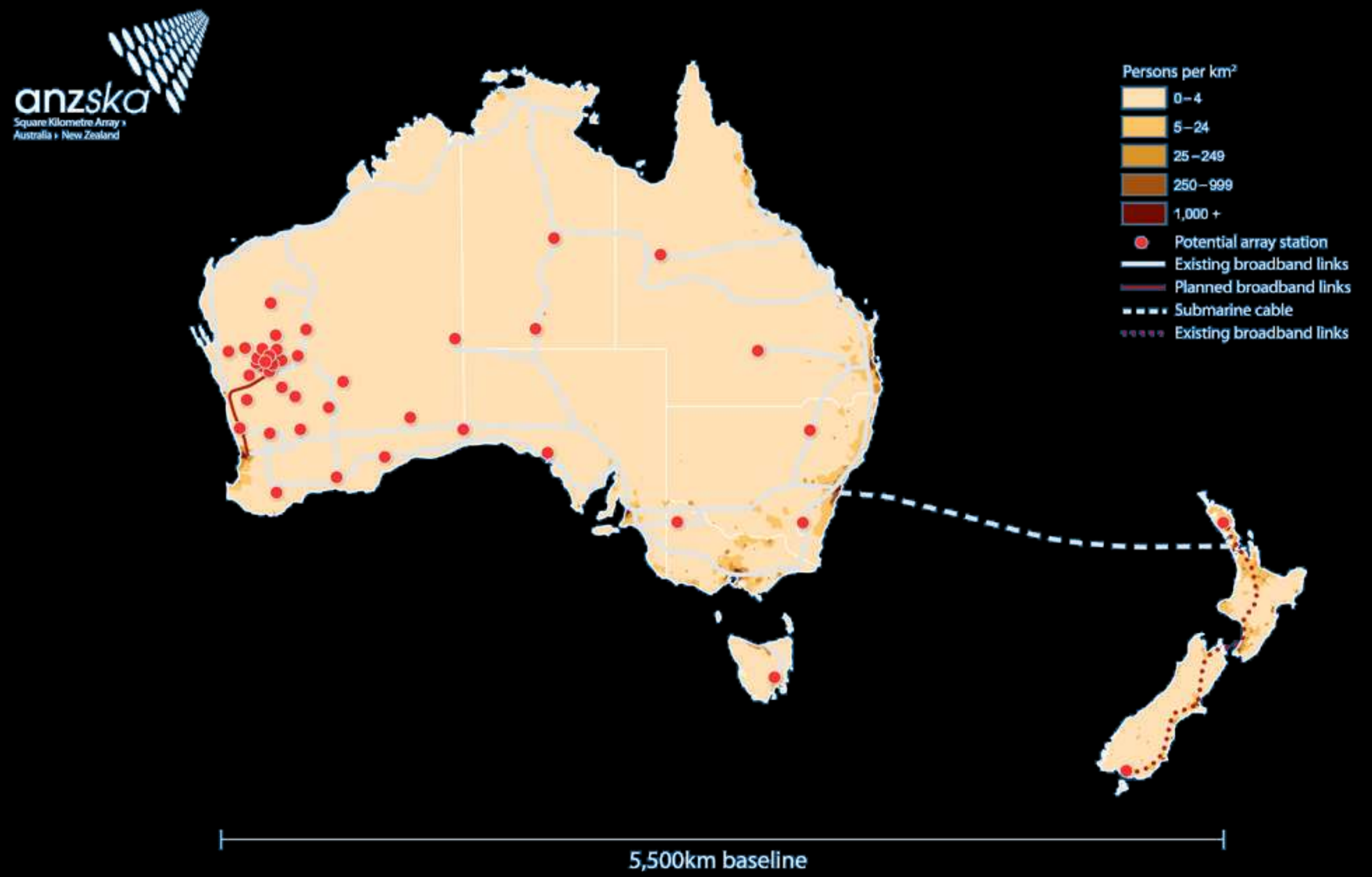
- A radio telescope needs a very radio quiet location, this generally means low population.
- General requirements
  - Away from towns or cities.
  - Flat space for hundreds of km.
  - Dry and geologically stable.
  - Access to technology and industry.
  - Accessible to the science community.
  - Stable economy and government.
- Current short listed countries are West Australia and South Africa.

China

Argentina

Southern Africa

Western Australia



anzska
Square Kilometre Array ›
Australia › New Zealand
Persons per km²
0 – 4
5 – 24
25 – 249
250 – 999
1,000 +
Potential array station
Existing broadband links
Planned broadband links
Submarine cable
Existing broadband links
5,500km baseline

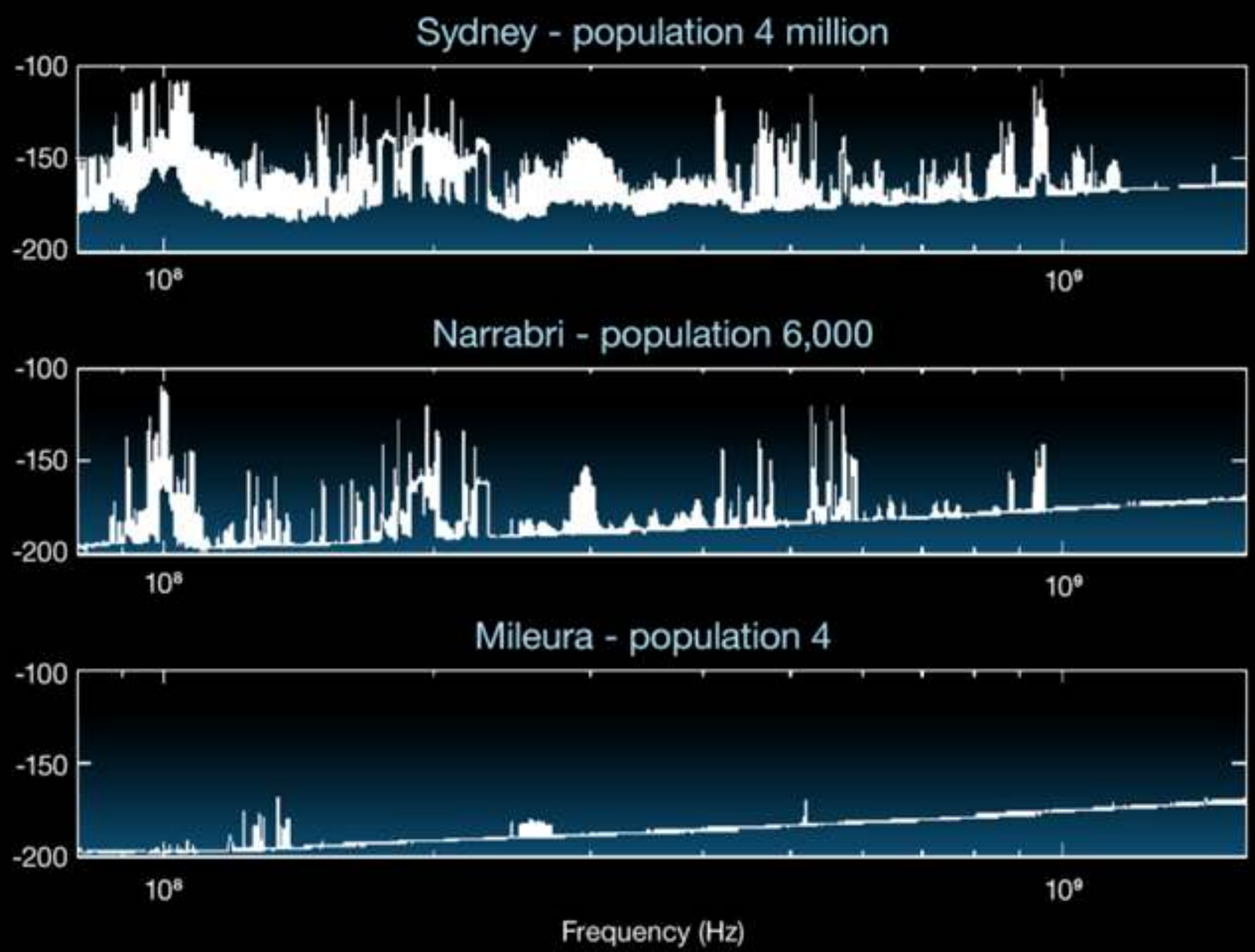
How quiet do we need to be?

Energy of a falling snowflake < 30 micro joules

Energy collected by ALL radio telescopes, ever is less than that of a falling snowflake

ASKAP: Australia SKA Pathfinder

- The SKA will not be built until 2020.
- In the meantime South Africa and Western Australia are building smaller instruments in order to solve technological problems.
- In Western Australia this is called the ASKAP: Australia SKA Pathfinder.

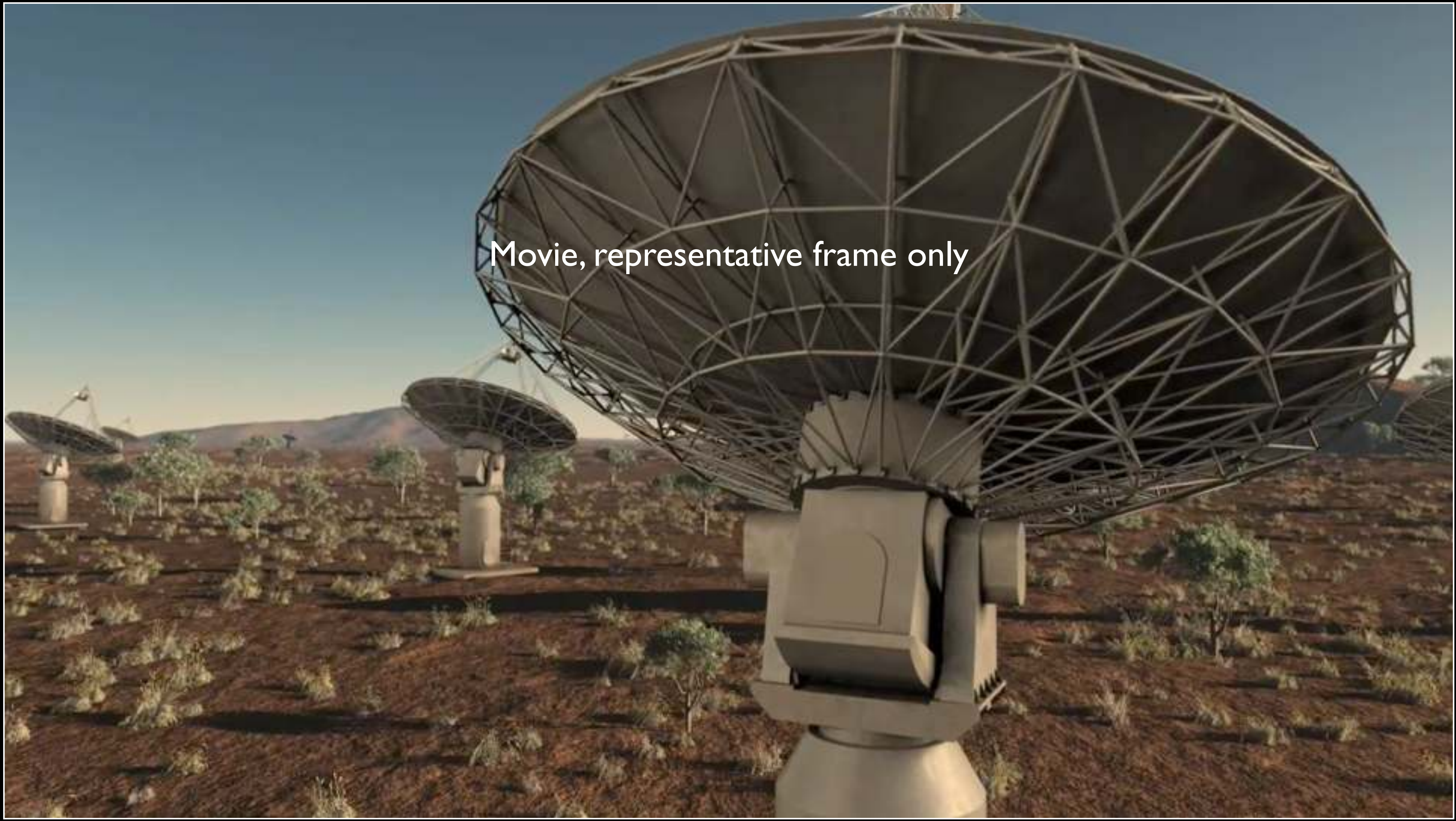


ASKAP summary

- Will consist of around 36, 12m diameter dishes.
- Even though ASKAP will only be a few percent of the SKA it will still be a very powerful radio telescope ad will do valuable science for the next 10 years.
- Should be fully operational by 2013, 6 dishes are on site now.

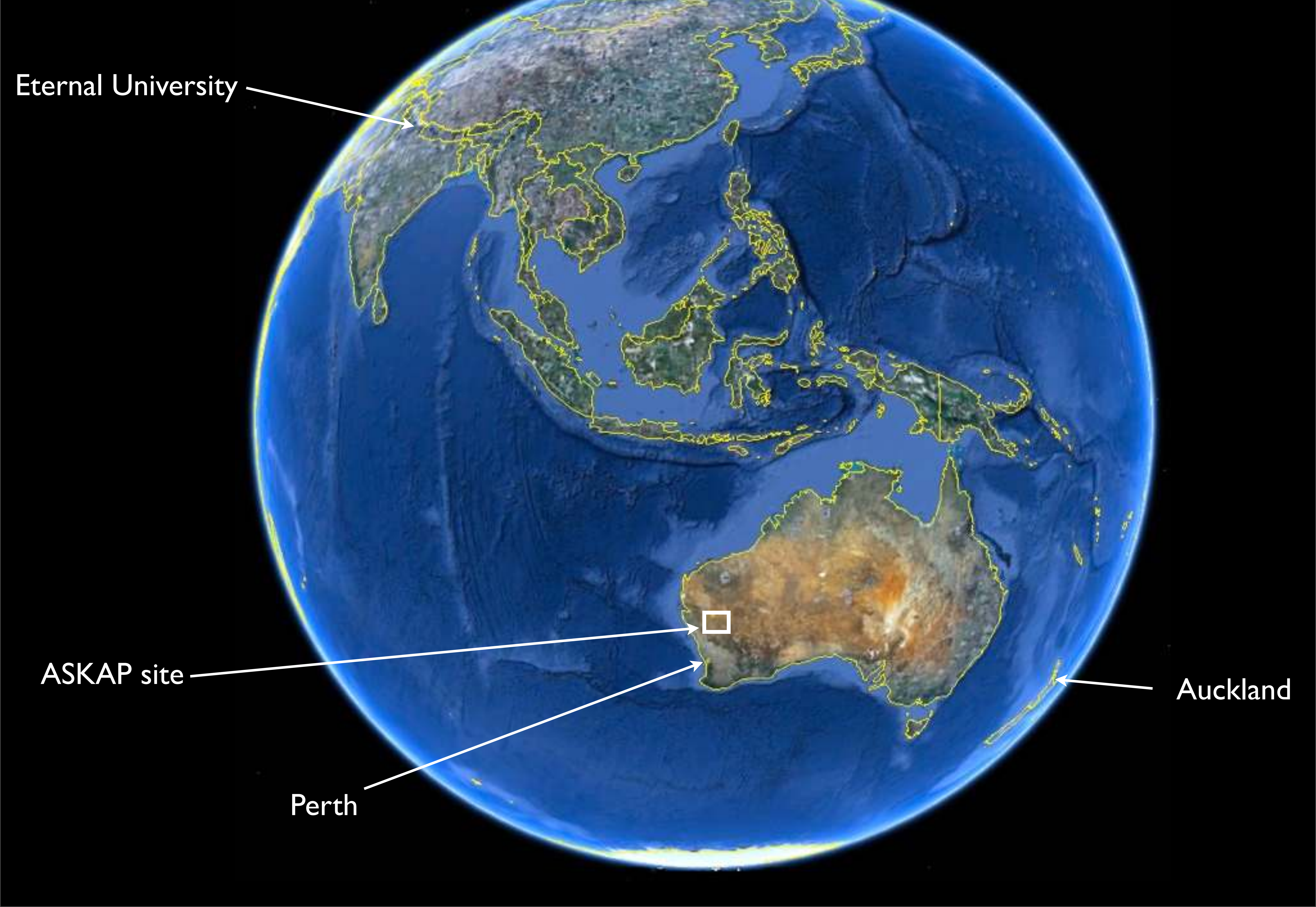
Chequer board sensor array on each dish

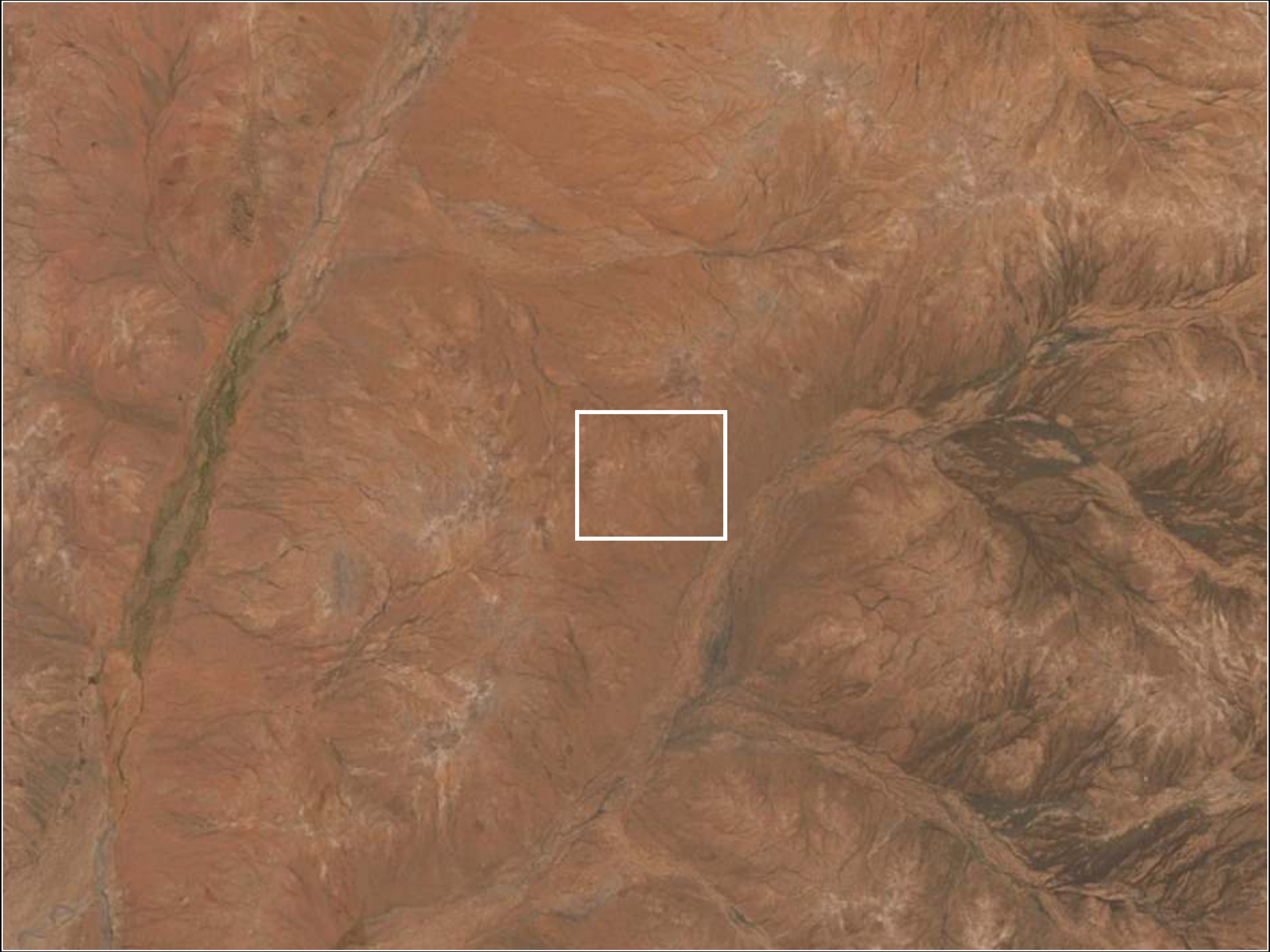
Artist impression

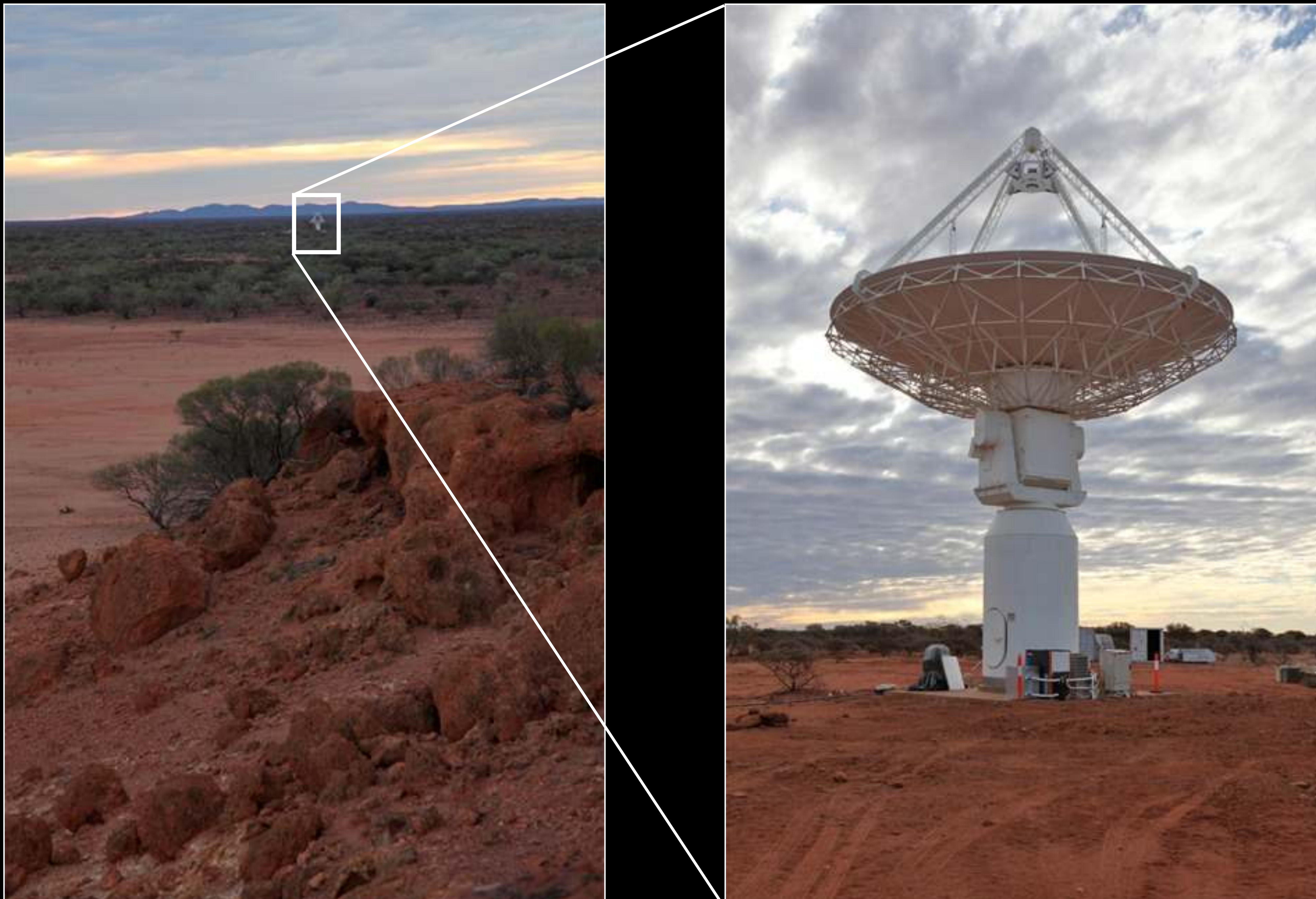


Astrophysics, Swinburne University

ASKAP site







How remote is it?

First dish - June 2010

Technological Challenges for the SKA

- Data generation and storage.
  Each hour it will collect more data than the entire world wide web.

- Network speed.
  It will require the worlds fastest network technology.

- Computer processing.
  It will require extremely powerful computers to process the data.
  1000 times the most powerful computer of today.

- Electricity.
  It will require highly renewable energy across a widely distributed array.

Meeting the technological challenges of the SKA will have a significant impact on many industries.

iVEC

- Building a sophisticated component of Australia's contemporary infrastructure
  - Supercomputing
  - High speed networks
  - Large scale data storage
  - Visualisation
  - Expertise

- Four programs
  - Supercomputing Technology and Applications (STAP)
  - Industry and Government Uptake
  - eResearch
  - Education

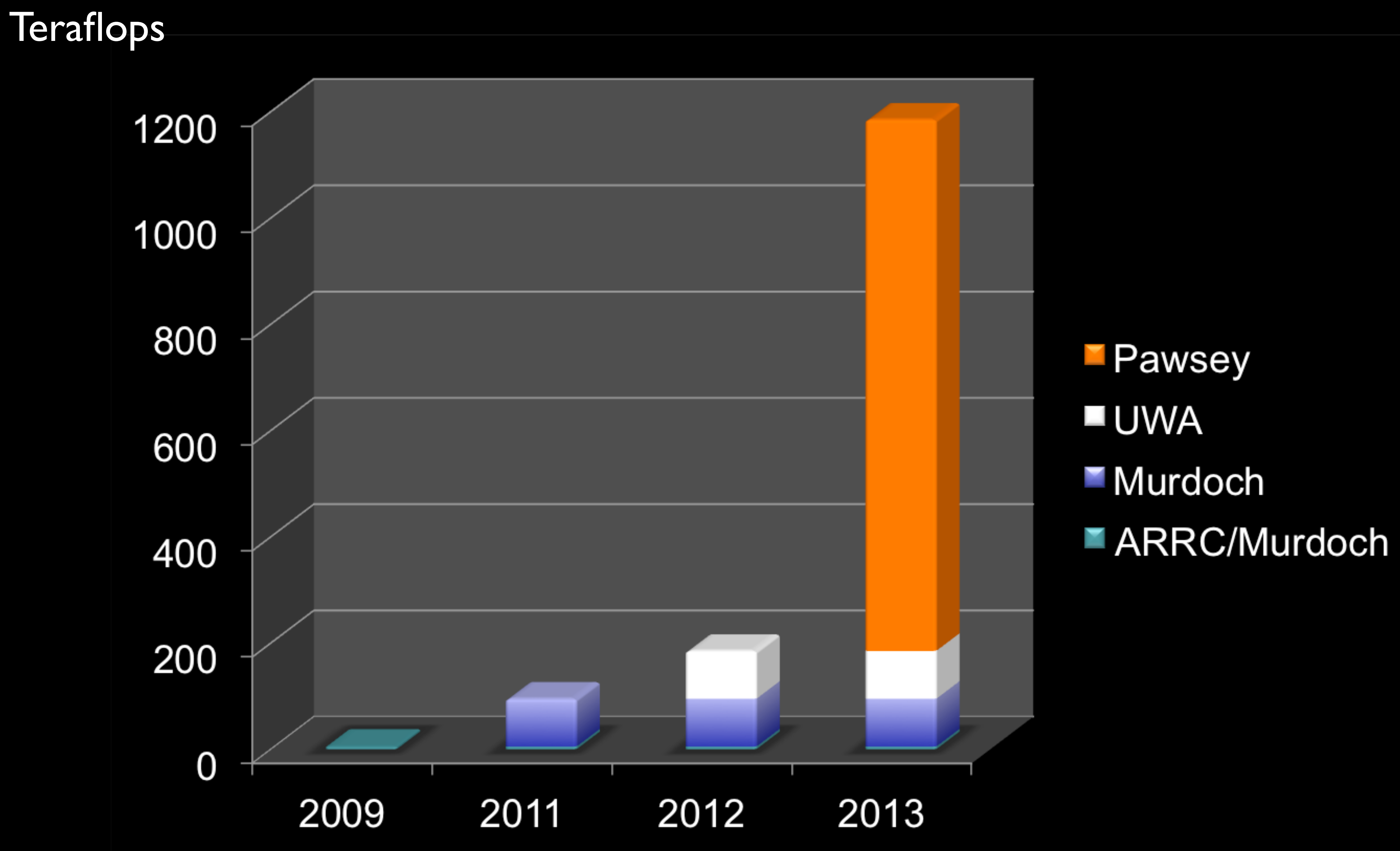
- Three Compute Facilities
  - iVEC@ARRC - Australian Resources Research Centre
  - iVEC@Murdoch - Murdoch University
  - iVEC@UWA - The University of Western Australia

iVEC, Pawsey and Superscience

- The Federal Government charged iVEC with the responsibility to establish and manage the $80 million Pawsey Supercomputing Centre for SKA Science in Perth.
- Will provide a world-class petascale supercomputing centre, placed to build towards meeting the enormous challenges associated with the computing and data processing capabilities of the SKA.
- Will constitute a hub for supercomputing that will support high-end research in many disciplines, including the geosciences, nanotechnology, biotechnology, engineering and atomic physics.
- Project goals

Provide an immediate significant boost to supercomputing capacity (100+TFlop/s)	
Expansion of capacity at existing iVEC Facilities	$9M
Develop world-class supercomputing expertise among researchers	
Design and construct a building and associated external infrastructure which will house the petascale supercomputing system	$30M
Design, procure and install a petascale supercomputing system	$40M

Exponential Growth in Supercomputing Capacity



iVEC@Murdoch: Pawsey stage 1a

iVEC@UWA: Pawsey stage 1b

- Fornax will be located in The University of Western Australia's Physics Building as part of the iVEC@UWA Facility and comprises 96 production nodes, each containing two 6-core Intel Xeon X5650 CPUs with 72GB RAM, and an NVIDIA Tesla C2075 GPU with 6GB RAM, resulting in a system containing 1152 cores and 96 GPUs.
- Fornax is a machine tailored for data-intensive computing in such areas as radio astronomy and the geosciences. The combination of GPUs and fast local disk distributed between neighbouring compute nodes provides a unique system for data-intensive researchers.

Pawsey Centre

Pawsey Centre

ASKAP - SKA Comparison

	ASKAP (1% of SKA)	**SKA**
Consultation Phase	2009 - 2012	2012 - 2021
Dish Antennas	36	3,000+
Receivers	7,200	600,000+
Software Engineering	Approximately 50 person years of software development	Approximately 5000+ person years of software development
HPC	100 Teraflops to 1 Petaflop	100's of Petaflops to 1 Exaflop
Data Storage	Product Rate: terabytes/day Data Archive: 10 Petabytes	Product rate: Petabytes/day Data Archive: Exabytes
Data Transmission	160 Gigabytes/sec	1,600 Gigabits/sec

Thank you.