Microwave Telescopes

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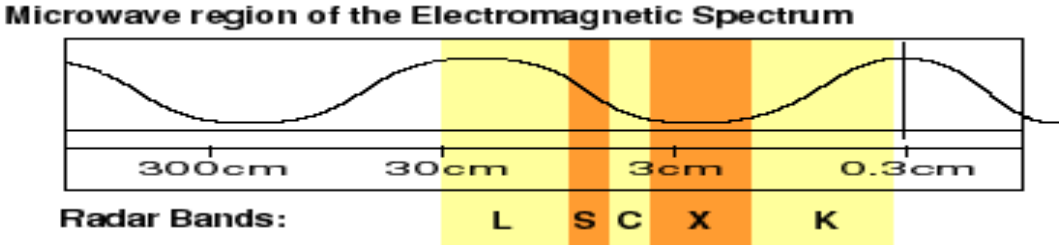
Discovery
(domestic use)



www.sabers.org/STELLA%20CANDY%20BAR.JPG

- Microwaves have wavelengths range from centimeters to those closer to a foot in length.
  - Longer are for heating food.
  - Shorter waves Doppler radar
- Microwaves were first utilized by British the 1940s during WWII.
  - Sir John Randall and Dr. H. A. Boot, invented a device called a *magnetron* (Radar) using microwaves to detect Nazi warplanes.
  - 1945, examining the magnetron, Percy Spencer's candy bar melted
  - Product was marketed, thank goodness Percy was a chocolate lover!

Cosmic Microwave Background (CMB)

- 1960's at scientists at Bell Laboratories detected background noise using a special “low noise” antenna.
- This static noise came from every direction and did not vary in intensity.
- The scientists soon realized they had discovered the cosmic microwave background radiation.

“This radiation, which fills the entire Universe, is believed to be a clue to it's beginning, something known as the Big Bang.”

Big Bang Model

Universe was once much smaller, hotter, and denser

- Based off of Einstein's theory of general relativity
- Expansion of the universe – 1929
- Lightest elements
  - Deuterium, helium, lithium
- CMB

What the CMB tells us about the Universe

- The geometry of the universe
- Whether the universe will expand or collapse
- How much matter there is in the universe
- Amount and nature of dark matter and energy
- Expansion rate of the universe
- Age of the universe
- The origins of galaxies and galaxy clusters

Origins of the CMB

- Universe cooled as expanded – became less dense
  - Density variations affected temp. of photons
    - Dense regions = hot spots in CMB
- 300,000 years – cooled enough to form atoms
  - Photons traveled through – form relic radiation
- Gravitational collapse – 1 billion years
  - Created galaxies

Brief History and COBE

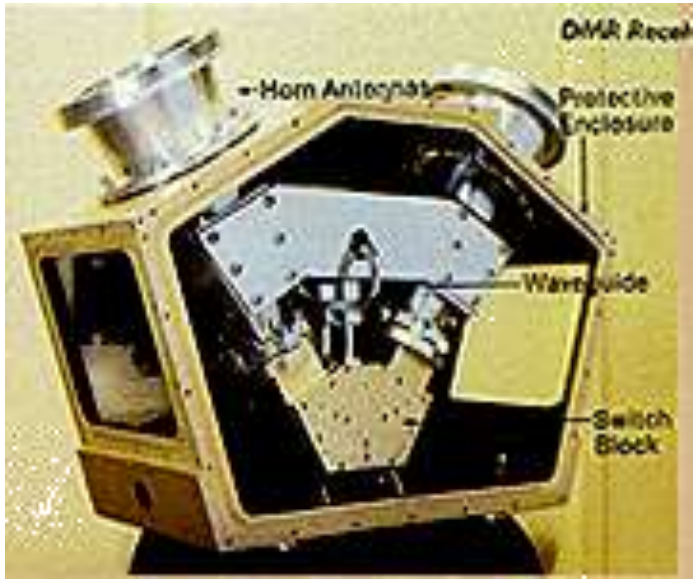
*"The cosmic microwave background radiation is a **remnant of the Big Bang** and the fluctuations are the imprint of density contrast in the early universe."*

•COBE (November 18, 1989- 1993)

Frequent observations were made over 6 mo. periods for 4 years.

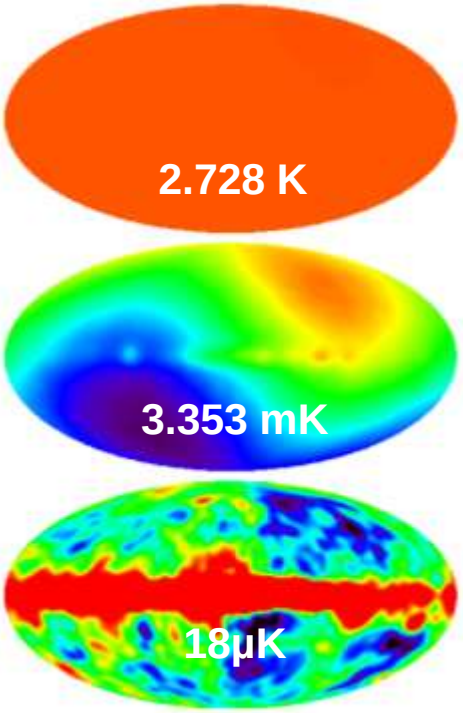
- •DIRBE (*Diffuse InfraRed Experiment*)
- • FIRAS (*Far-InfaRed Absolute Spectrophotometer*)
- • **DMR (*Differential Microwave Radiometers*)**

DMR Receiver



Differential Microwave Radiometer

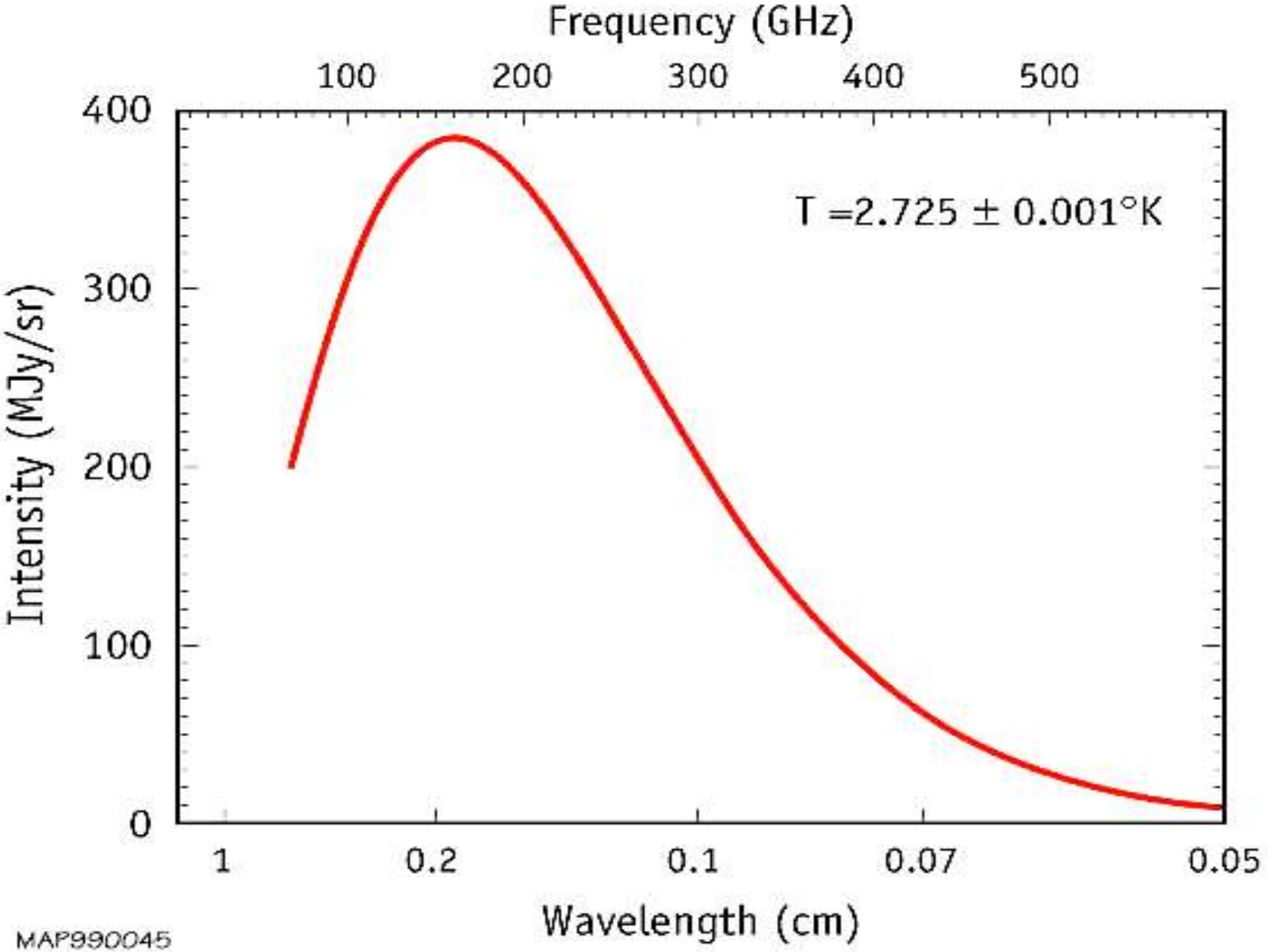
COBE's findings at different levels of contrast:



Variations in intensity of the cosmic microwave background, show the post-Big Bang matter and energy distribution.

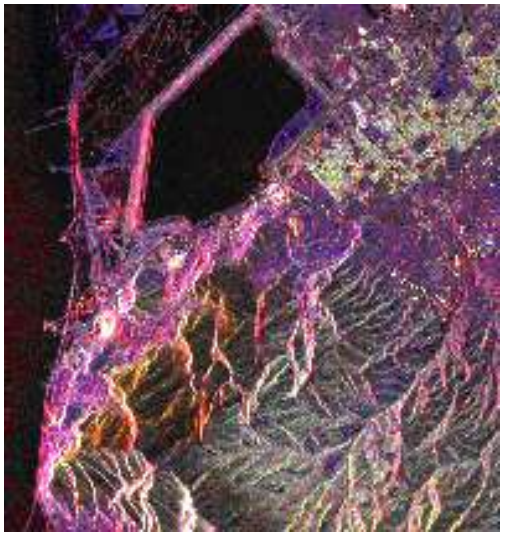
- Uniformity / Isotropic CMB (*top*)
  - temperature of CMB
- Black body curve (*middle*)
  - One hot and cold spot in the sky coming from our Solar System's motion through the galaxy.
- Density Ripples (bottom)
  - Further contrast "with our local motion removed." hot red stripe through the center marks the galactic plane and above and below are variations in microwaves of the CMB!

Spectrum of the Cosmic Microwave Background



What are Microwaves used for?

- Heating, transmitting information, remote sensing
  - Shorter microwaves used for remote sensing
    - Doppler radar
      - Active remote sensing system
    - Microwaves pierce through all cloud covering of earth
      - Satellite images



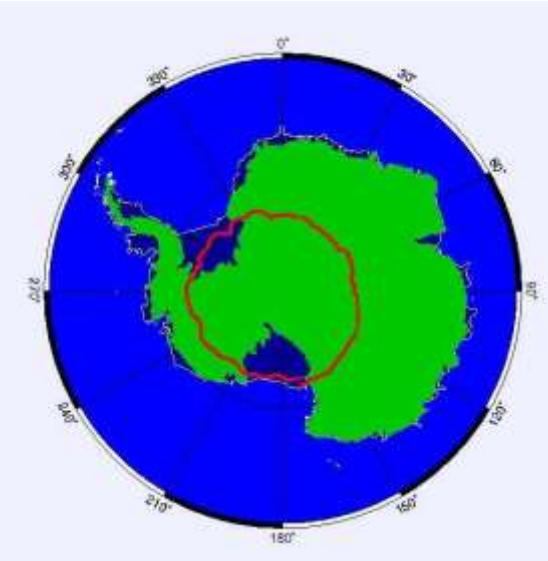
http://imagers.gsfc.nasa.gov/ems/micro.html

Archeops

- Balloon Born Telescope
- Aims
  - High quality CMB data with unmatched sky coverage
    - Competitive results on CMB anisotropy measurements
  - Testbed for data analysis to be used in PLANCK

Boomerang

- Balloon born telescope
  - Dec. 29, 1998 – Jan. 9, 1999
    - 10.5 days around antarctica
    - 120,000 ft
  - 1.2 m primary mirror
  - Measured sky at 4 frequencies
    - 90, 150, 240, 400
  - Covered 1800 square degrees (3% of sky)



http://cmb.phys.cwru.edu/boomerang/press_images/cmbfacts/cmbfacts.html

Cosmic background Imager

- radio telescope to study CMB radiation
  - Measure the statistical properties on angular scales from 5 arc minutes to one degree
  - 13 element interferometer
    - Field of view – 44 arcmin
    - Resolution – 4.5-10 arcmin

•Looks at foreground
•Unresolved sources measured by 40 m telescope in Owens Valley Radio Observatory

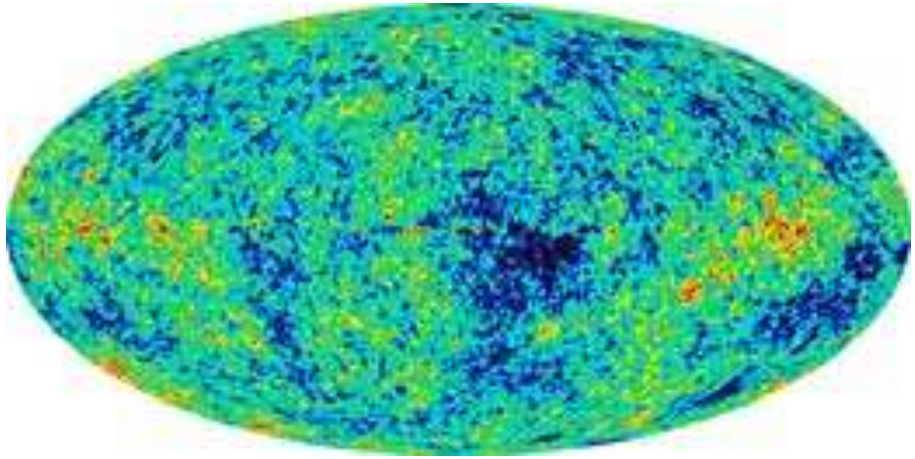
http://www.astro.caltech.edu/~tjp/CBI/pictures/cbi-frontview.html

DASI

- Degree Angular Scale Interferometer
- 13 elemental interferometer
- Measure temp and angular power spectrum
- Sampled over *l* range of 160-170 or .25-1.15 degrees
- Mount includes rotation of aperture plane along line of sight

WMAP

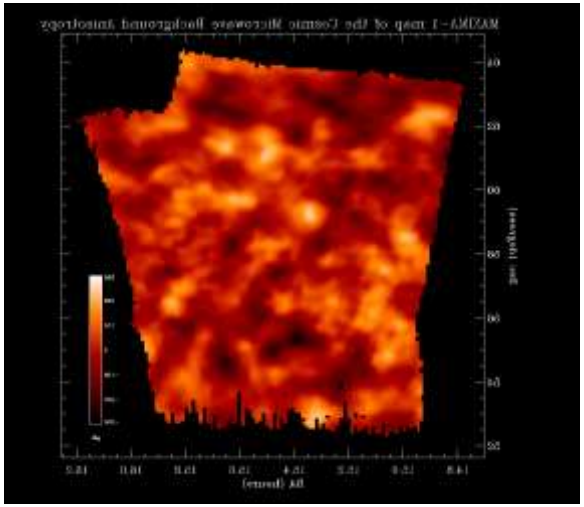
- Wilkinson Microwave Anisotropy Probe
- Launched 2001 to map CMB radiation with higher resolution, sensitivity, and accuracy than COBE



http://map.gsfc.nasa.gov/m_mm/sg_earlyuniv.html

MAXIMA

- **M**illimeter **A**nisotropy e**X**periment **Im**aging **A**rray
- angular power spectrum with a unique set of "acoustic peaks" between the angular scales of 2 degrees and 10'
  - can provide precise estimates of cosmological constants

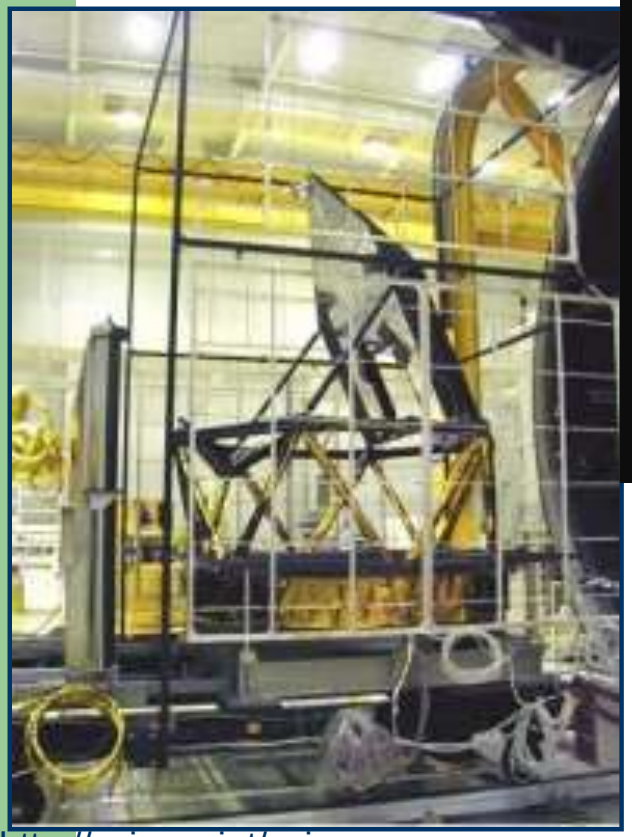


http://cosmology.berkeley.edu/group/cmb/image/maxima_map.gif

Plank

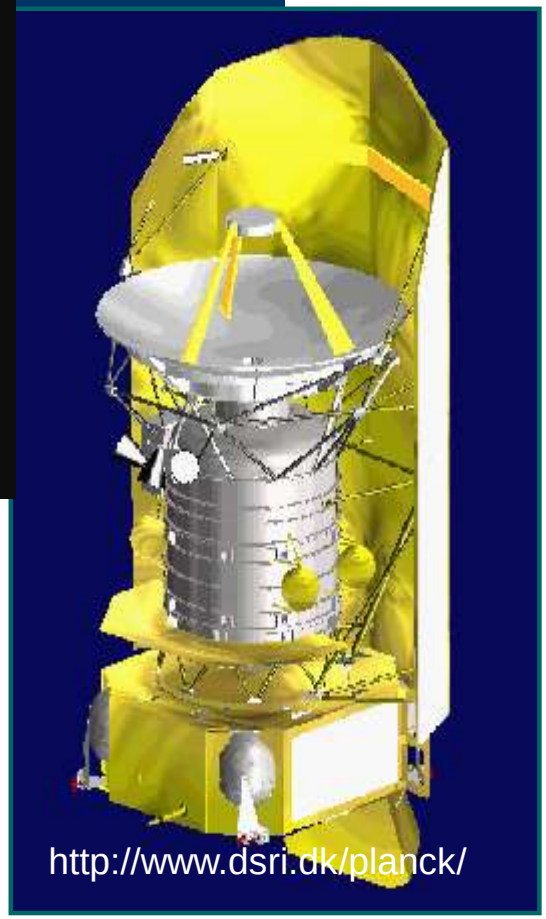
- Part of the first European mission to study the “birth” of the Universe
- Construction to be finished in 2005
- Launched in the same rocket with Herschel in 2007
- Will observe the Cosmic Microwave Background (left over radiation from the Big Bang)

PLANK



http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=34875

http://spaceflightnow.com/news/n0006/13planck/

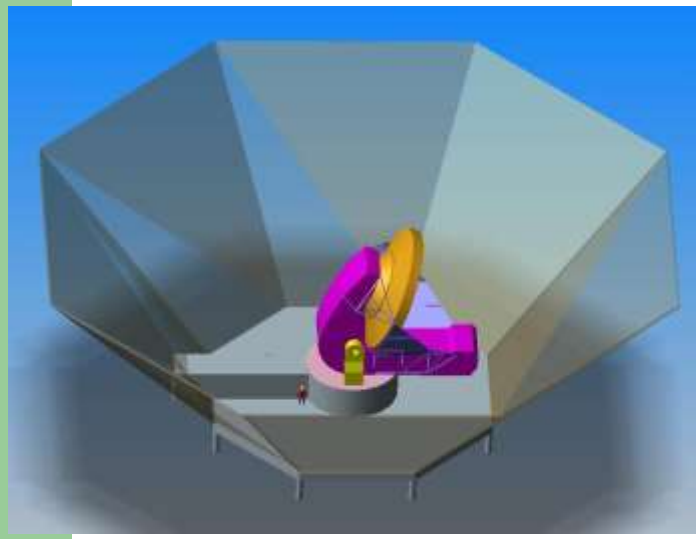


http://www.dsri.dk/planck/

The South Pole Telescope (SPT)

- An 8-meter precision submillimeter-wave telescope
- Distant galaxy clusters through detection of their Sunyaev-Zel'dovich effect (SZE)
- Dark Energy will be observed in great detail
- 1,000 Bolometers (heat detectors) measure the temperature differences up to 10 millionths of a degree
- Mapping large areas of the sky will be very beneficial to modern astronomers

The South Pole Telescope

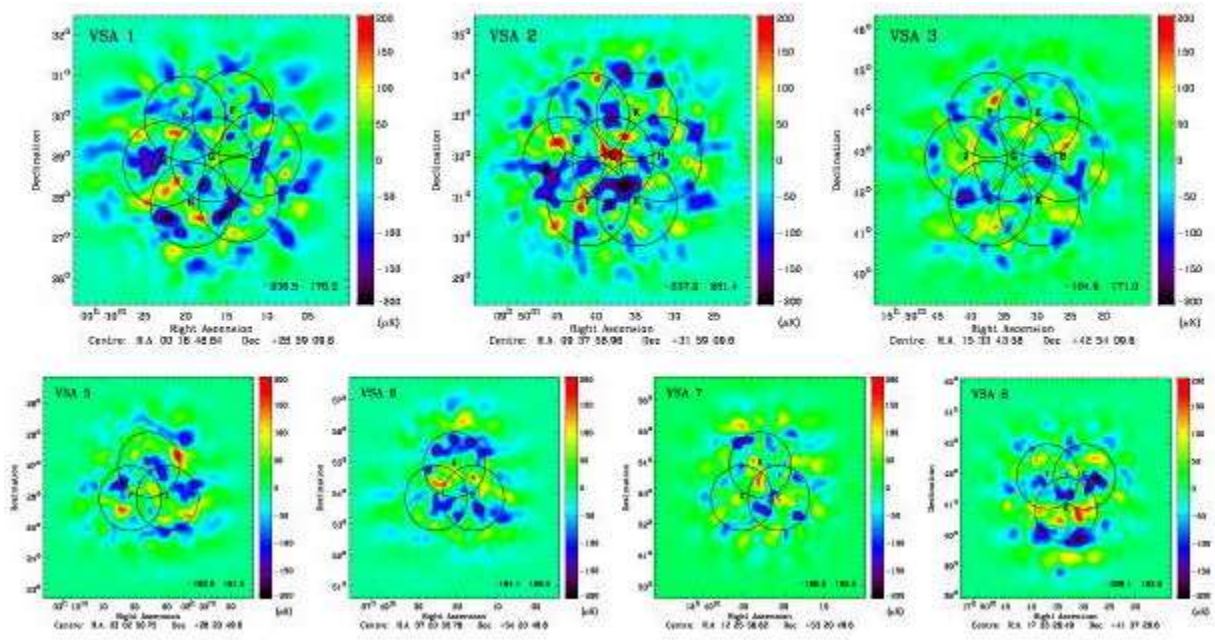


http://astro.uchicago.edu/spt/

http://www.spaceflightnow.com/news/n0301/29polescope/

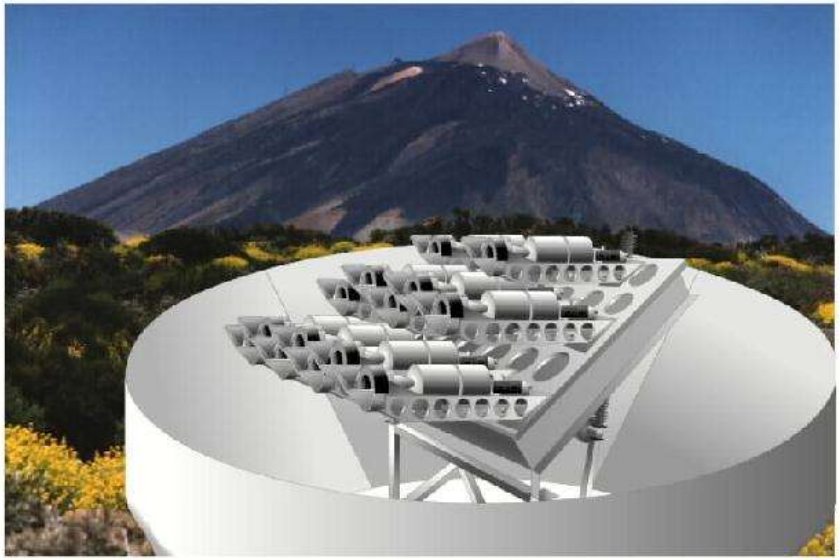
The Very Small Array (VSA)

- Will be built as an Inferometer, due to the changing [redacted] instruments that are experienced
- Uses radio signals received by each antenna
- Construction finished in 1999→ now in Tenerife



http://www.mrao.cam.ac.uk/telescopes/vsa/

Very Small Array



The Very Small Array, Tenerife

www.mpifr-bonn.mpg.de/.../teleskope/vsa_art1.jpg

www.jb.man.ac.uk/tech/technology/array-top.jpg

www.mrao.cam.ac.uk/telescopes/vsa/ext-array.jpg

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