
the Very Large Array (VLA)
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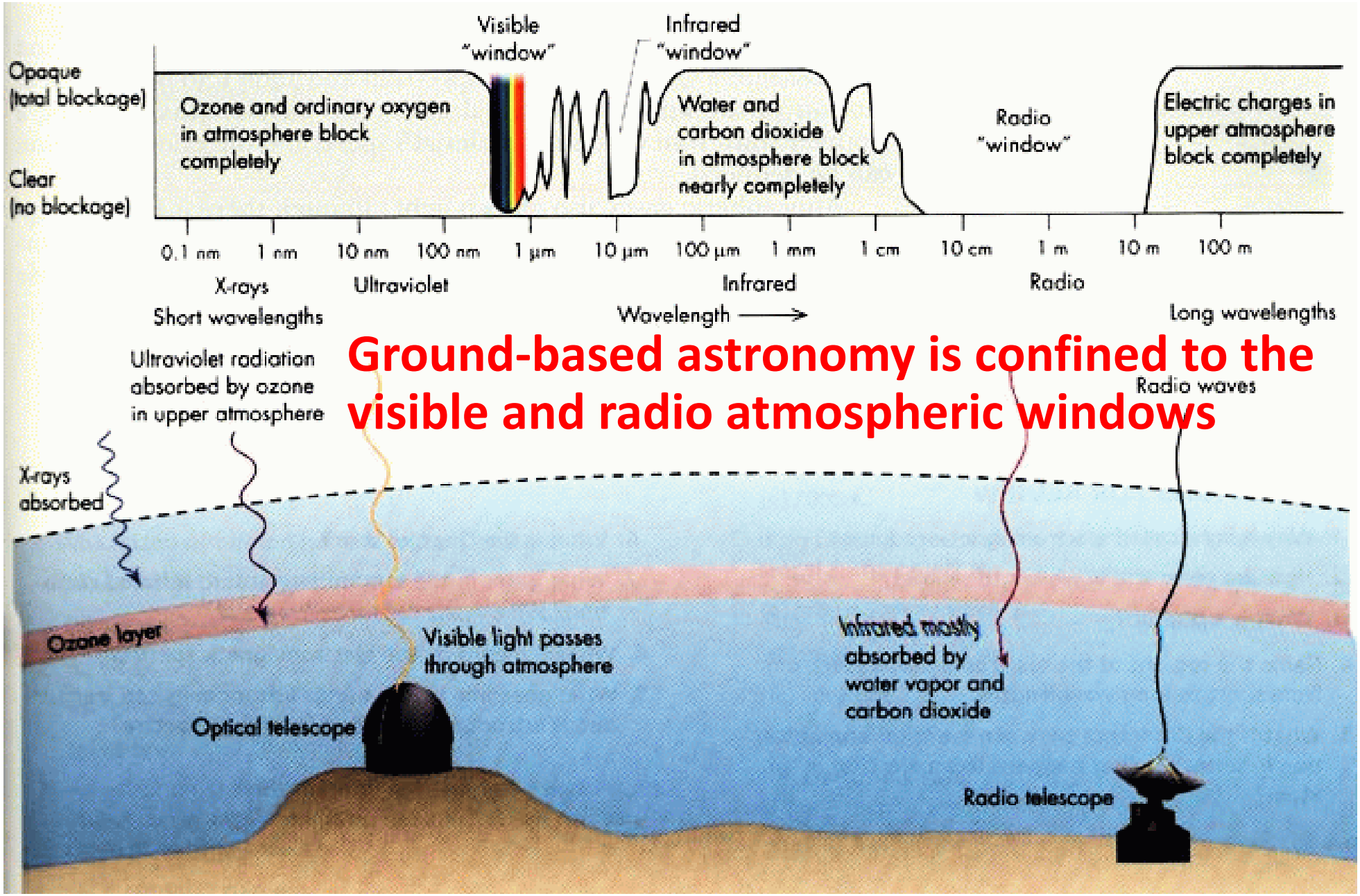
Student seminar, 3/16/2018

Content

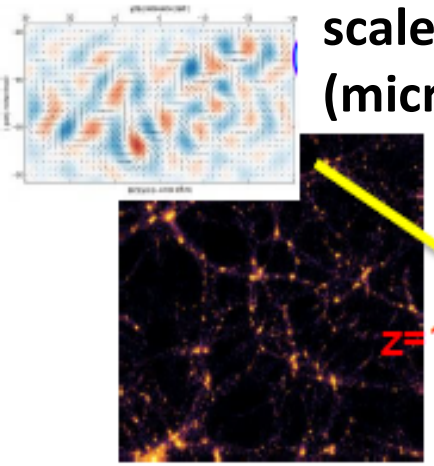
- Introduction to radio astronomy
- VLA basic
- VLA discoveries
- VLA surveys

Windows to the universe

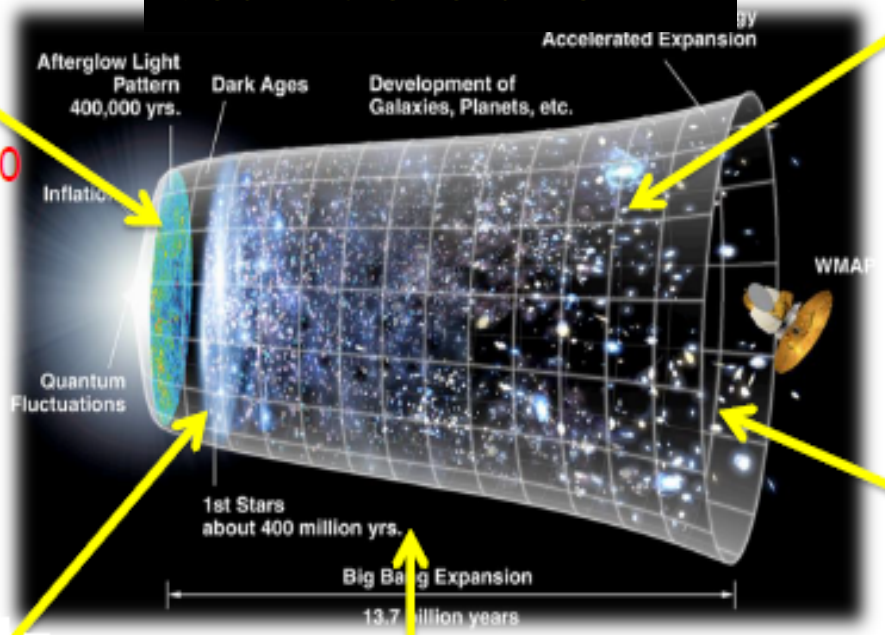


Radio Astronomy : major science

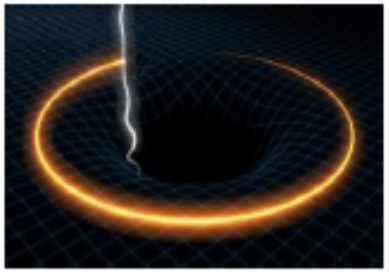
CMB & Large scale structure (microwaves)



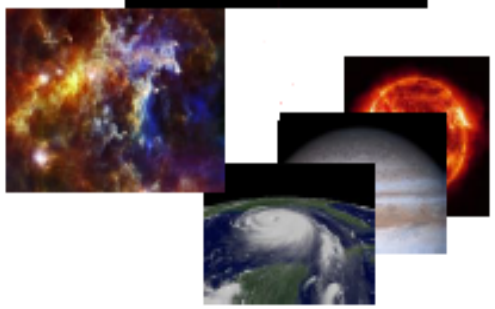
Cosmic evolution



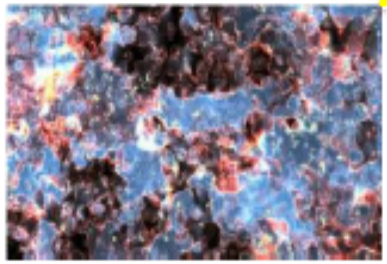
Quasars, pulsars



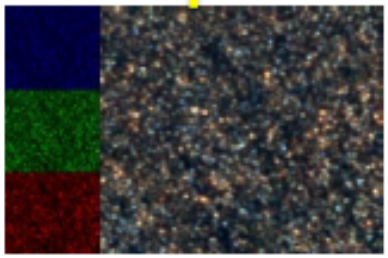
Planets, Interstellar molecules, SETI



First Stars and Galaxies (21cm)



Galaxy evolution

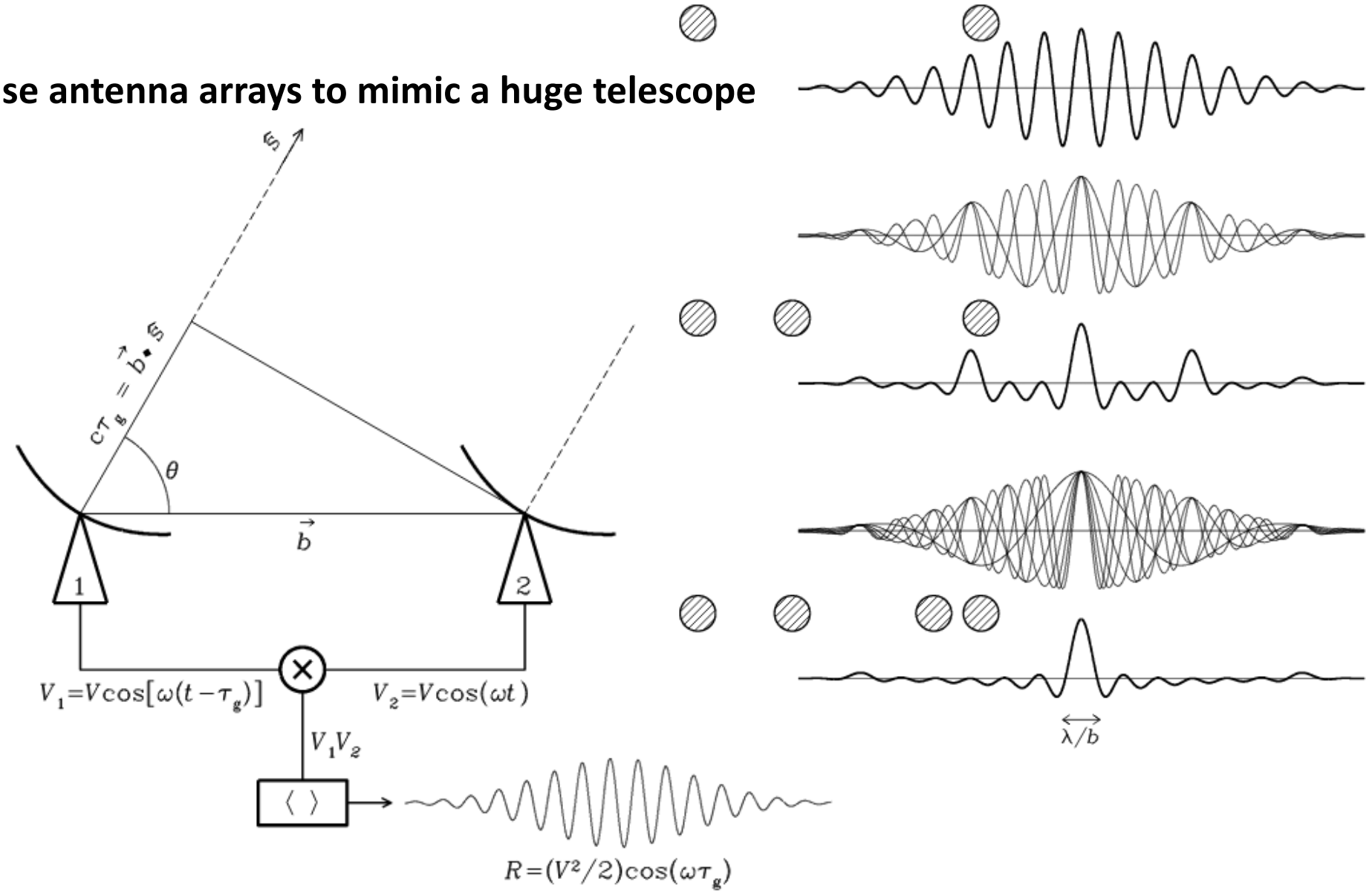


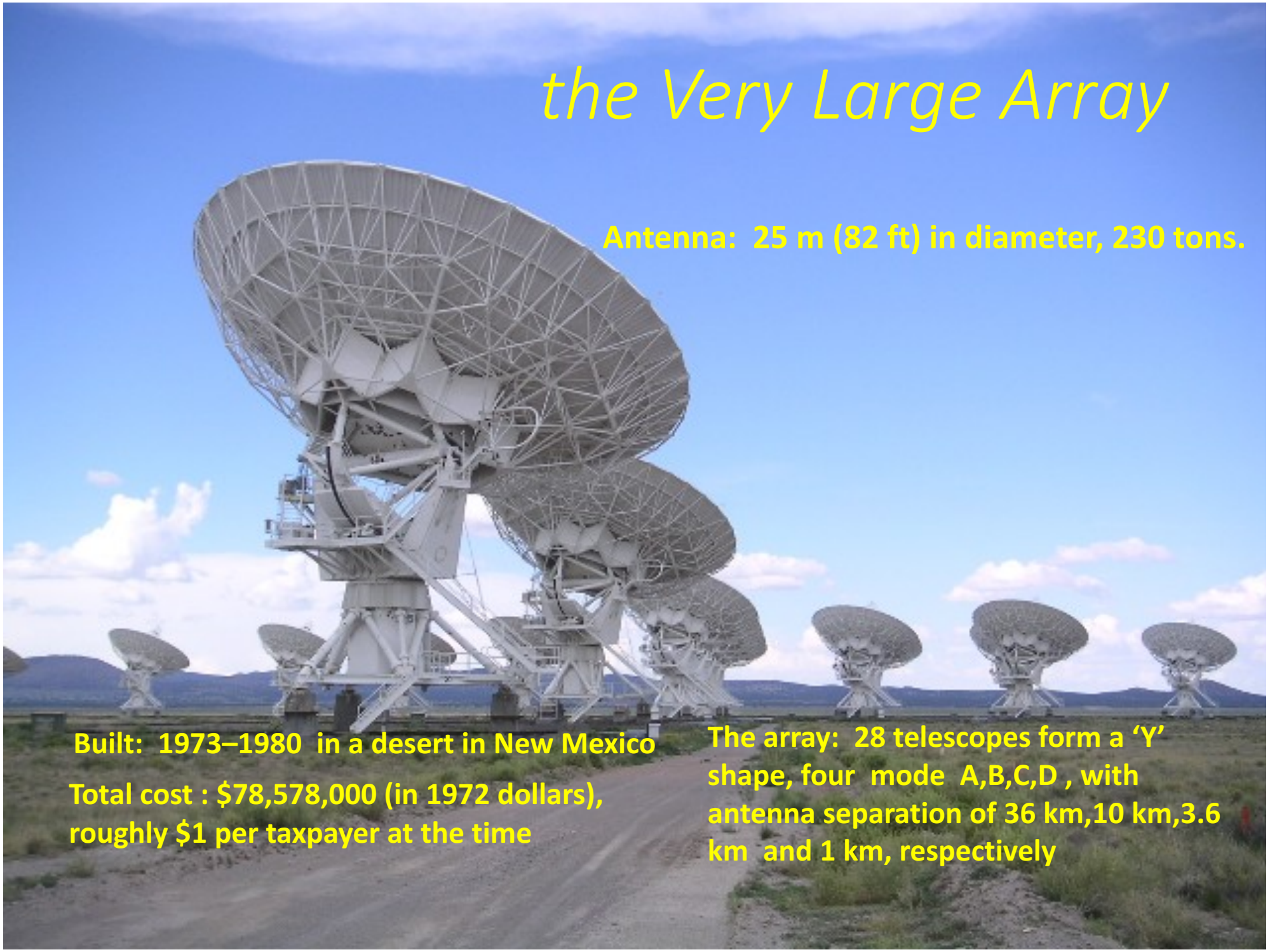
Radio Astronomy : Telescopes

- ***Antenna*** : converting electromagnetic radiation in space into electrical currents in conductors or vice-versa
- ***Radiometer*** : a radio receiver used to measure the average power of the noise coming from a radio telescope in a frequency range

Radio Astronomy : Interferometer

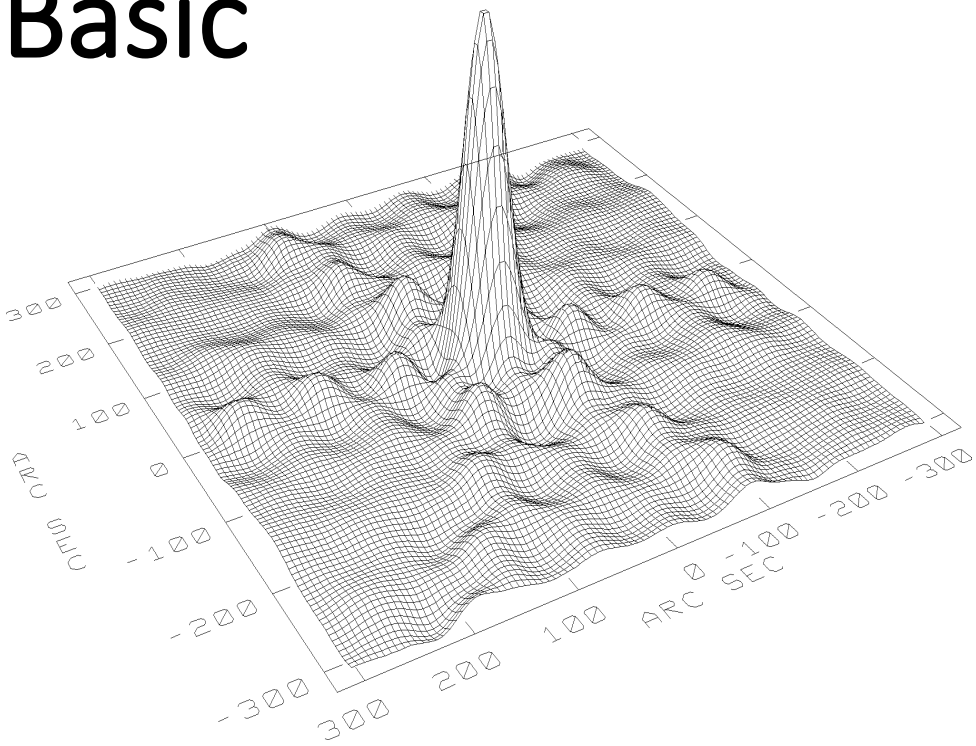
Use antenna arrays to mimic a huge telescope




the Very Large Array
Antenna: 25 m (82 ft) in diameter, 230 tons.
Built: 1973–1980 in a desert in New Mexico
Total cost : $78,578,000 (in 1972 dollars), roughly $1 per taxpayer at the time
The array: 28 telescopes form a 'Y' shape, four mode A,B,C,D , with antenna separation of 36 km,10 km,3.6 km and 1 km, respectively

VLA : Basic

- Interferometer achieves imaginary spatial resolutions



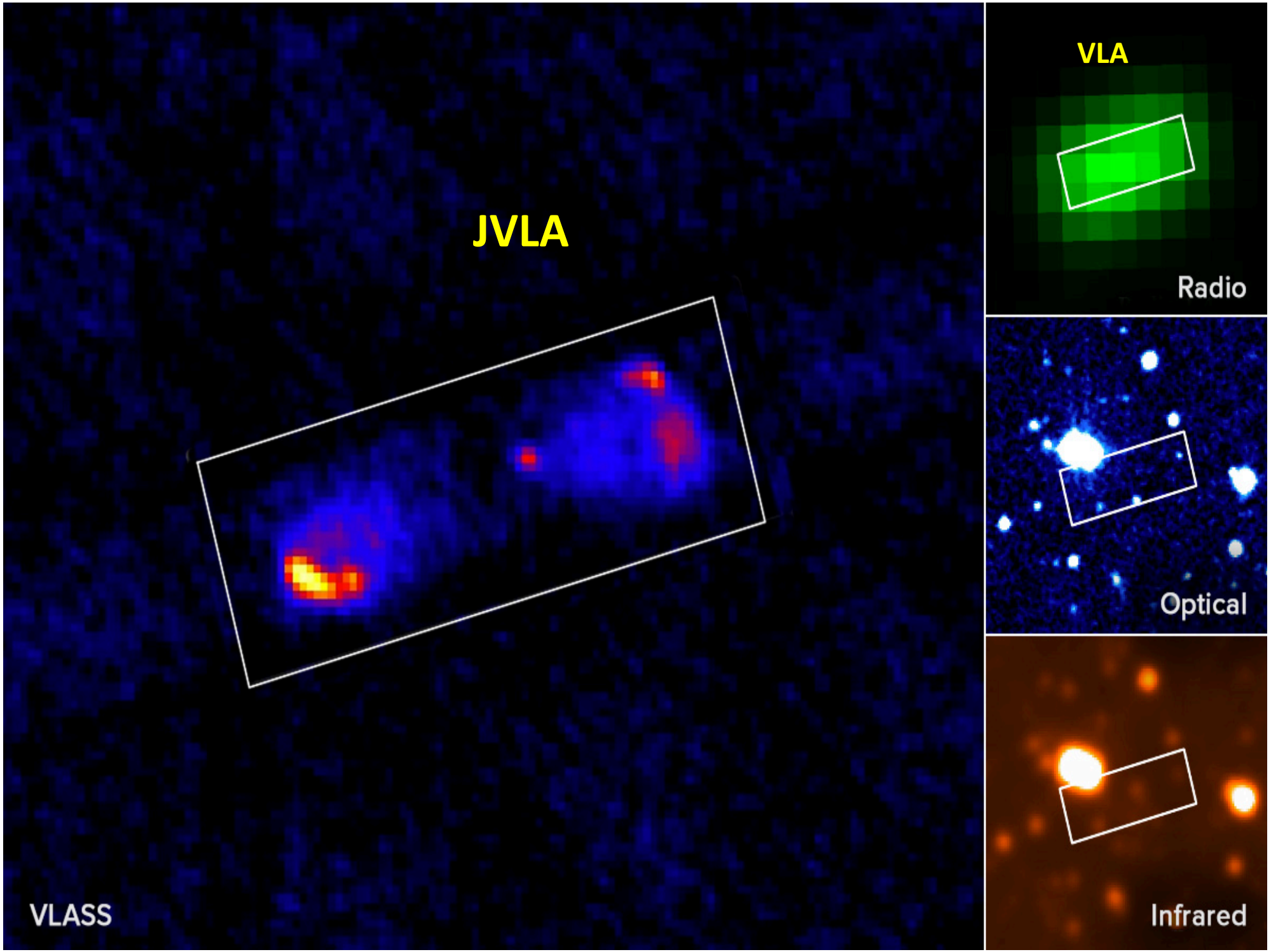
Receivers Available at the VLA								
	4 Band	P Band	L Band	C Band	X Band	U Band	K Band	Q Band
Frequency (GHz)	0.073-0.0745	0.30-0.34	1.34-1.73	4.5-5.0	8.0-8.8	14.4-15.4	22-24	40-50
Wavelength (cm)	400	90	20	6	3.6	2	1.3	0.7
Primary beam (arcmin)	600	150	30	9	5.4	3	2	1
Highest resolution (arcsec)	24.0	6.0	1.4	0.4	0.24	0.14	0.08	0.05
System Temp	1000-10,000.K	150-180.K	37-75.K	44.K	34.K	110.K	50-190.K	90-140.K


Configuration A : 22 mile array diameter
Configuration B : 7 mile array diameter
VLA View of Hercules A
Configuration C : 2 mile ar
e array diameter

Make VLA great again — JVLA

An overhaul of the antennas + installation of a fiber-optically fed supercomputer = a state-of-the-art instrument
The Karl G. Jansky Very Large Array from 2012.3.31

Parameter	VLA	JVLA	Factor
Point Source Cont. Sensitivity (1σ,12hr.)	10 μJy	1 μJy	10
Maximum BW in each polarization	0.1 GHz	8 GHz	80
# of frequency channels at max. BW	16	16,384	1024
Maximum number of freq. channels	512	4,194,304	8192
Coarsest frequency resolution	50 MHz	2 MHz	25
Finest frequency resolution	381 Hz	0.12 Hz	3180
# of full-polarization spectral windows	2	64	32
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	5

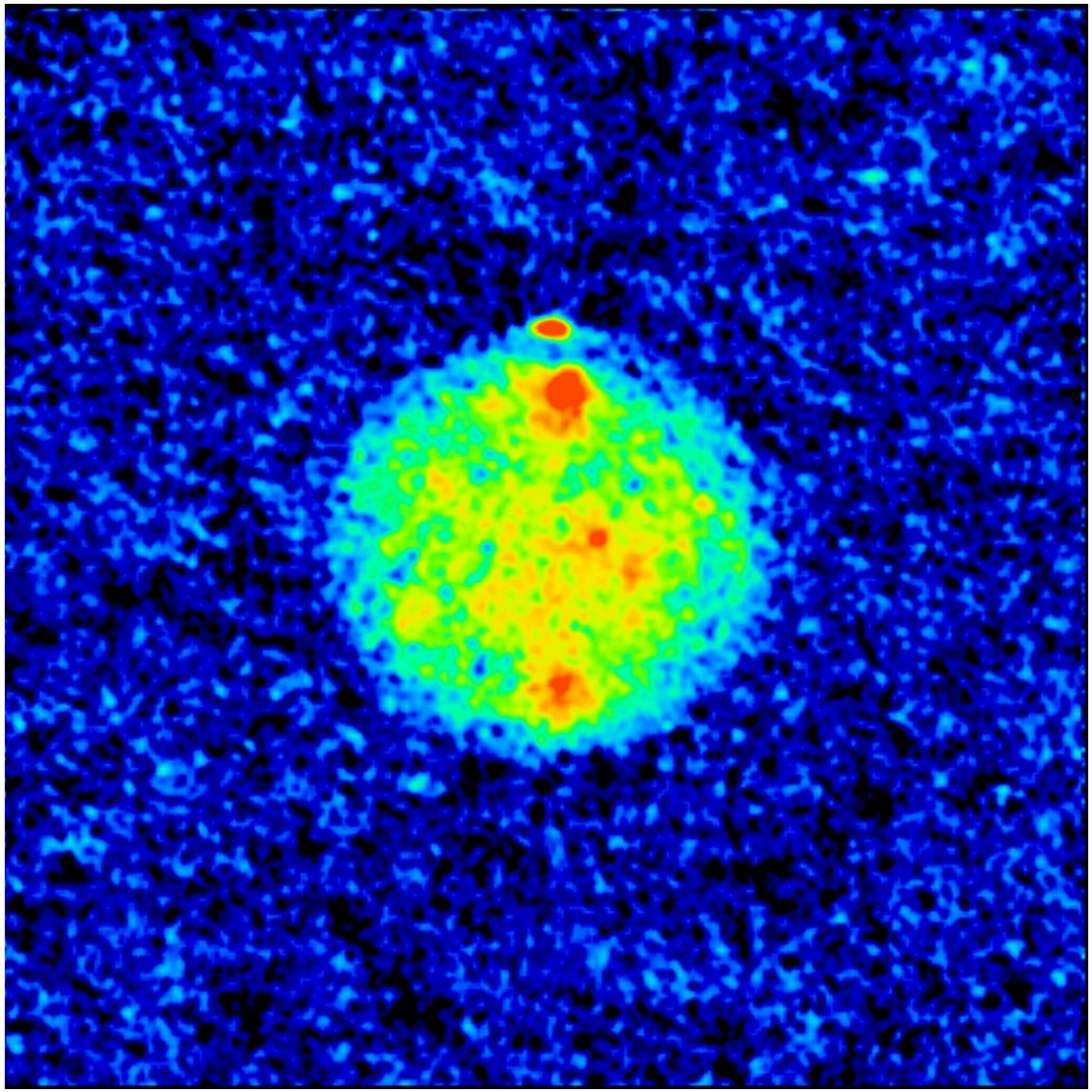

JVLA
VLASS
VLA
Radio
Optical
Infrared

VLA Science : discoveries

- Ice on Mercury (Butler et. al. 1993)
- "Microquasars" in Our Galaxy (Mirabel & Rodriguez 1994)
- Revealing the Shrouded Center of the Milky Way (Zhao & Goss 1998)
- Seeing Channels, changes, and inner parts of Superfast Cosmic Jets (e.g. Gizani et al. 2003)
- The First "Einstein Ring" Gravitational Lens (Hewitt et.al. 1988)
- Discovery of radio waves from Gamma Ray Bursts helps locate them(Dale Frail & Shri Kulkarni 1997)
- Carbon Monoxide disk in galaxy in early universe (Richards et.al 1998)
- Super massive black hole in a dwarf starburst galaxy (Reines et.al. 2011)
- First stages of planet formation (Wilner et.al. 2000)

Ice on Mercury

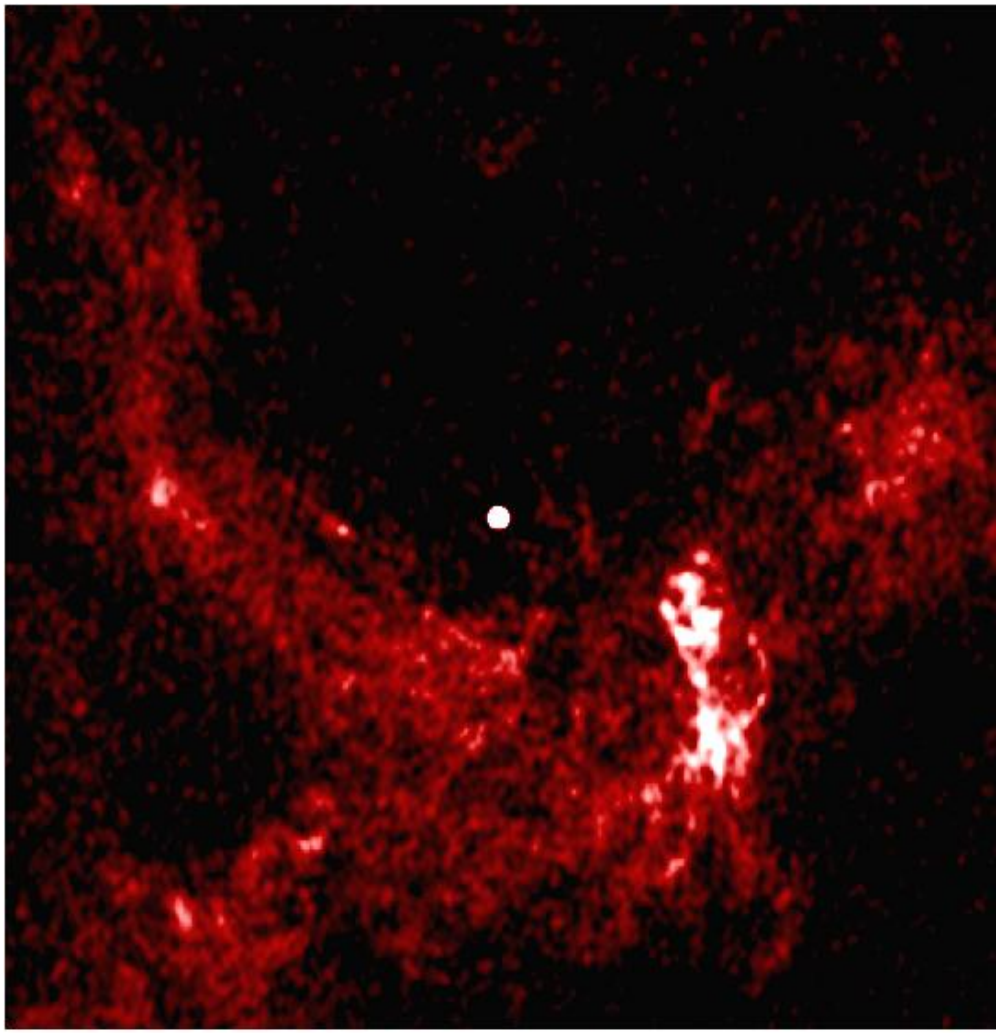
- Planet Radar
- 8.5-GHz microwaves
- Sent from a radar system consisting of NASA's 70-meter dish antenna at Goldstone bounced off Mercury collected at the VLA



Center of our Galaxy

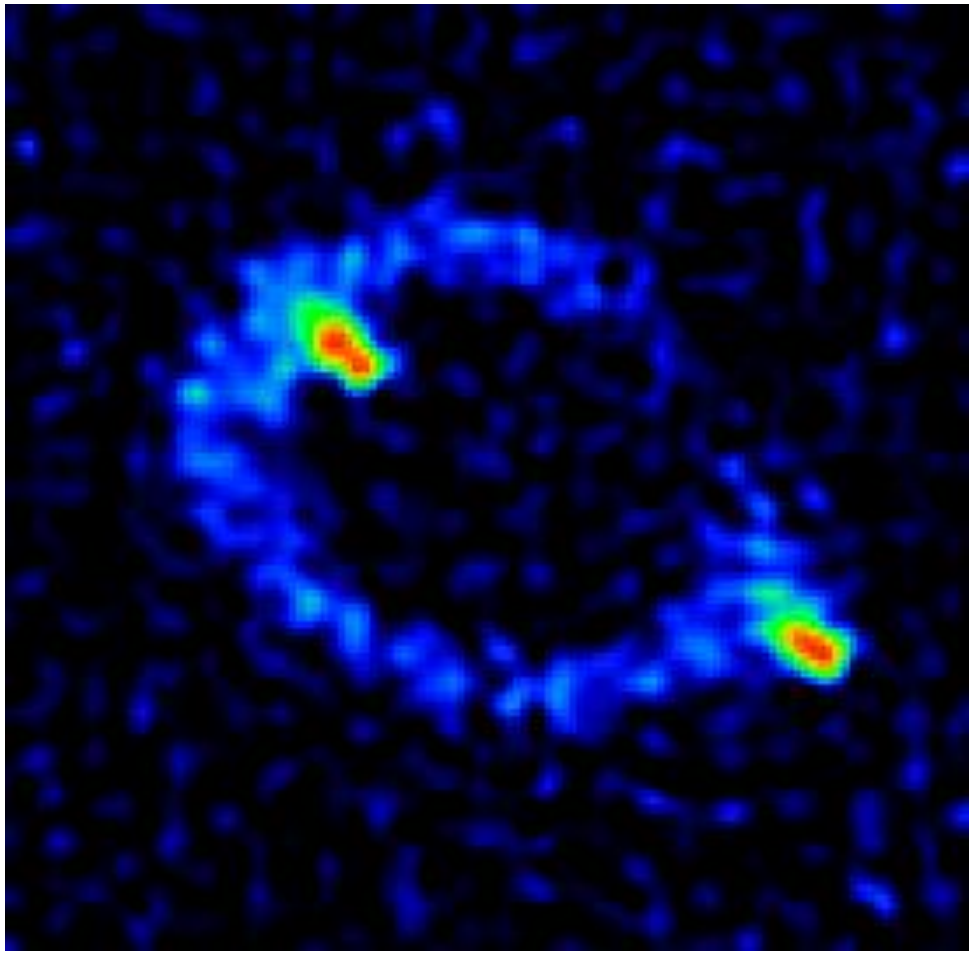
- Shrouded by dust from optical telescopes, but visible to radio telescopes

- From 1982 to 1998, astronomers observed Sgr A* with the VLA to measure its apparent motion



The First "Einstein Ring"

- MG1131+0456, proved as a distant quasar lensed by a galaxy
- Discovered in early 1987, using VLA two-minute “snapshot” images.



VLA Science : surveys

- Faint Images of the Radio Sky at Twenty-Centimeters (FIRST) : radio equivalent of the Palomar Observatory Sky Survey over 10,000 square degrees of the North and South Galactic Caps (Becker et.al. 1995)

- The NRAO VLA Sky Survey (NVSS): a 1.4 GHz continuum survey covering the entire sky north of -40 deg declination (Condon et. al. 1998)

- The Very Large Array Sky Survey (VLASS) : an on going survey with JVLA

NVSS : Scientific Goals & Survey Design

- Two major distinct populations of extragalactic radio sources : strong point sources (e.g. quasars), fainter but diffuse sources (e.g. HII regoins, low-luminosity AGN)

- We need low resolution to detect low-brightness source but high resolution to determine accurate positions

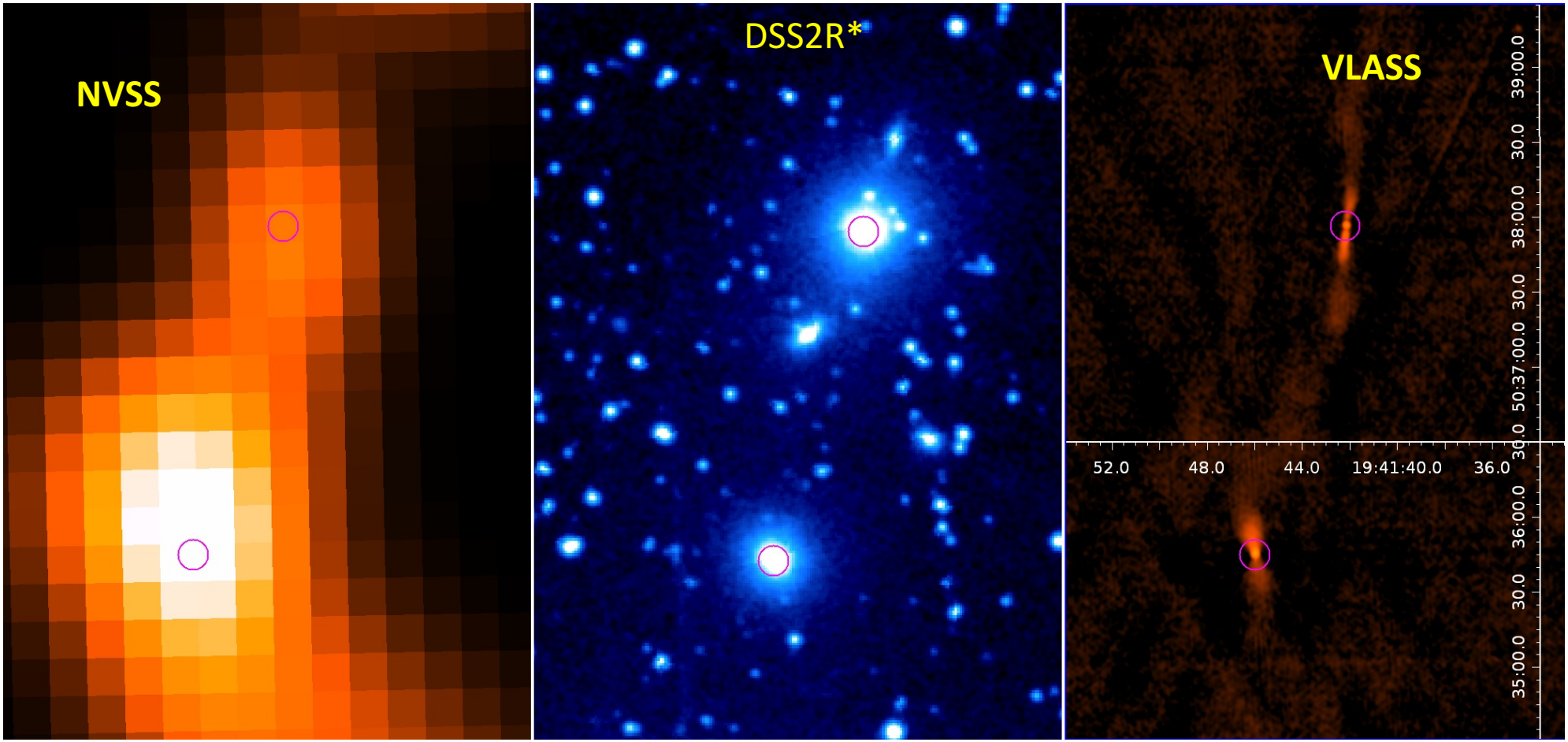
- Considering the maximum sensitivity at 1.4GHz, NVSS runs in D and DnC configurations – aiming to detect 10^2times more star forming region and thousands of nearest faint AGN

NVSS : major results

- A set of 2326 continuum image cubes, each covering 4 deg X 4 deg with an angular resolution of 45 arcsec.
- A catalog of discrete sources on these images (over 1.8 million sources in the entire survey).
- Huge amount of papers, 3577 citations to Condon et. al. 1998

VLASS : Mapping sky with JVLA three times

- After the major upgrade, JVLA can run a survey with higher resolution than any previous ones



VLASS : Mapping sky with JVLA three times

- High resolution (B and B&A configurations)
- Ability to find transient objects

VLASS Summary	
Frequency	2-4GHz
Resolution	2.5 arcsec
Sky coverage	All Sky North of Dec. -40 deg. (33885 deg^2)
Sensitivity per epoch	120 μJy RMS
Combined (3 epoch) sensitivity	69 μJy RMS
Polarization	I,Q,U
Cadence	3 epochs separated by 32 months
Start Date	September 15 2017
Expected number of sources	~5,000,000

Summary

- Interferometer arrays with imaginary spatial resolutions are efficient tools in mapping the radio sky
- VLA is one of the most widely used and productive radio telescopes all over the world
- Upgrades are never stopped to keep VLA being a state-of-the-art instrument, putting forward the radio astronomy even further