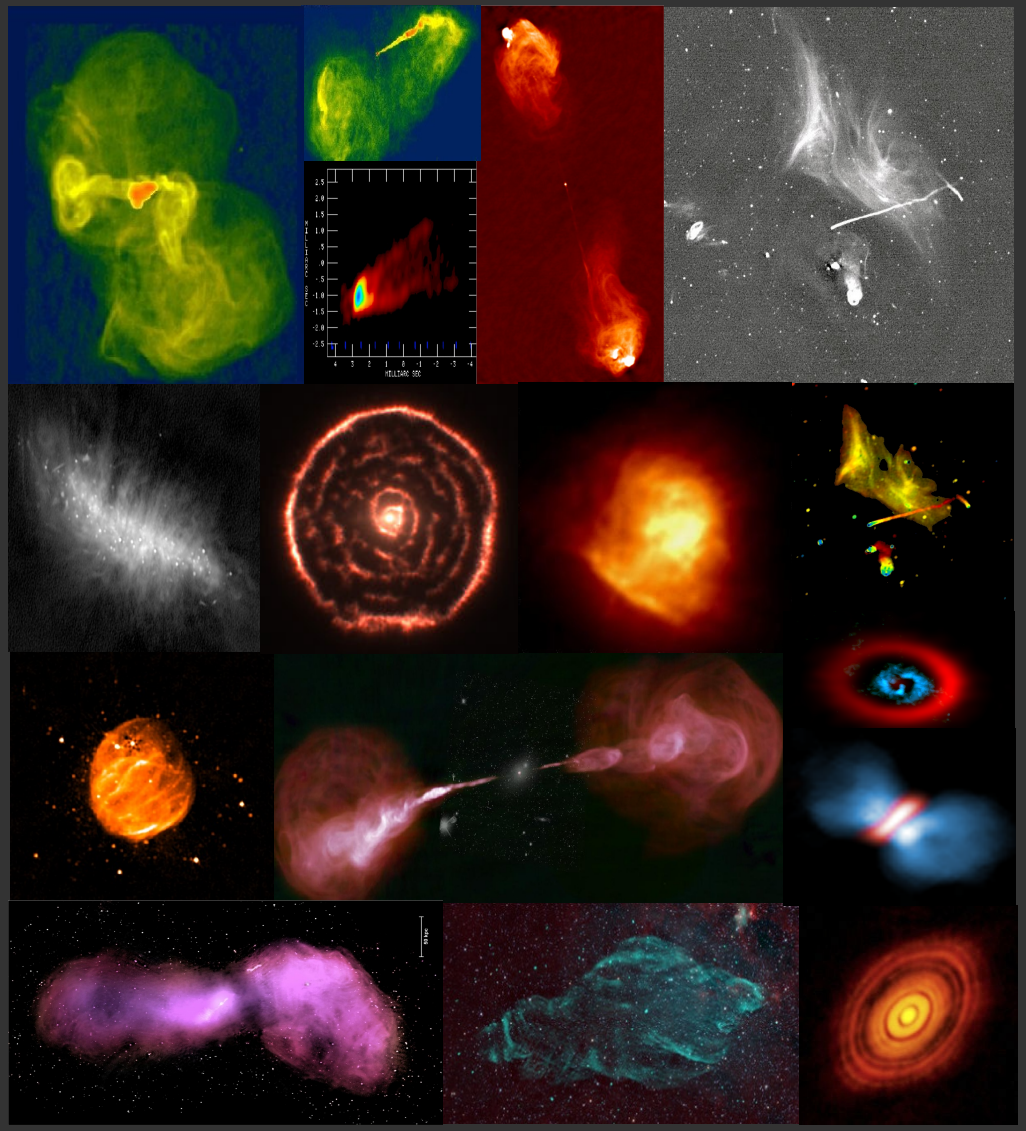
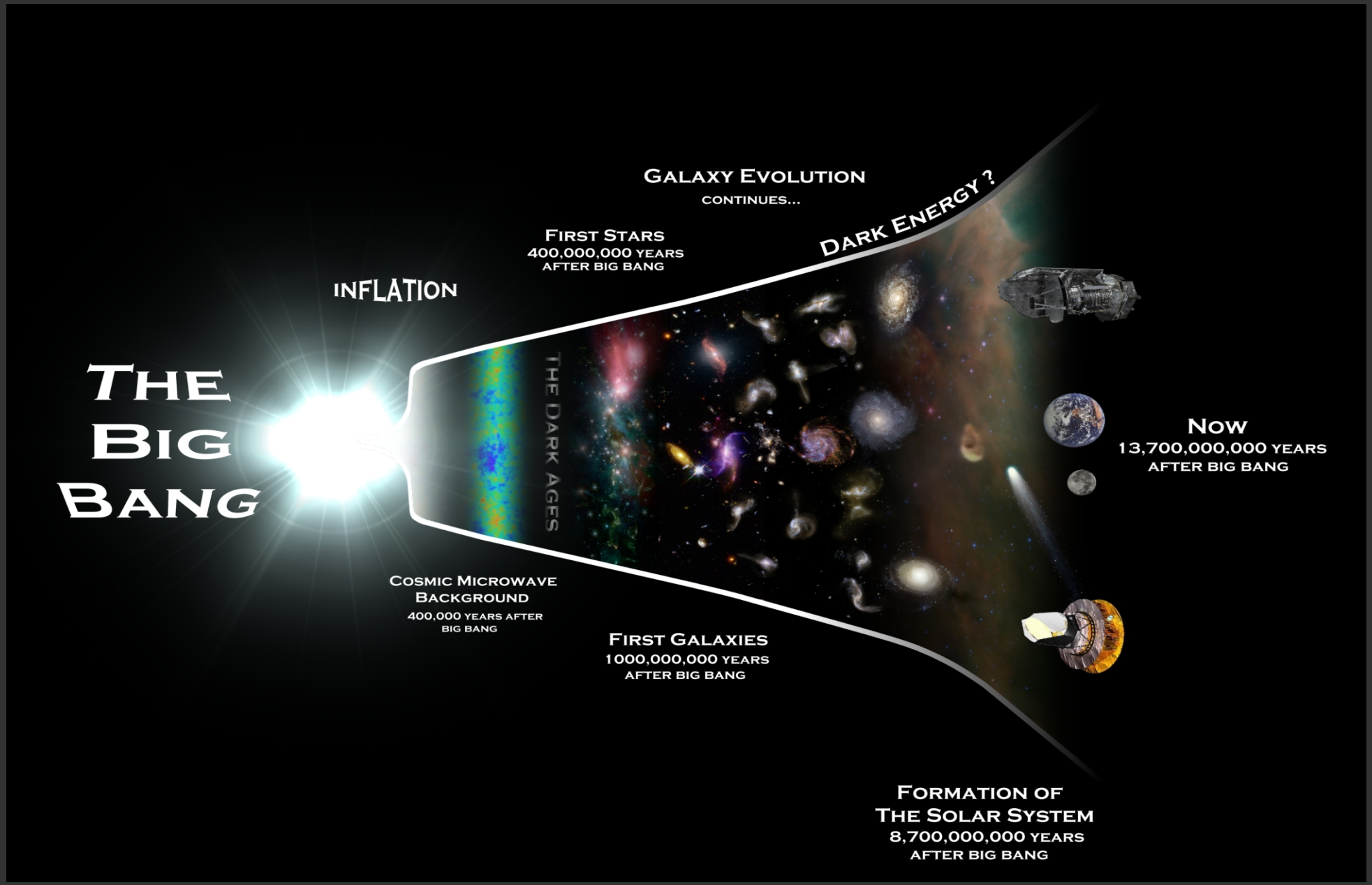
Astronomy and Telescopes



Urvashi Rau

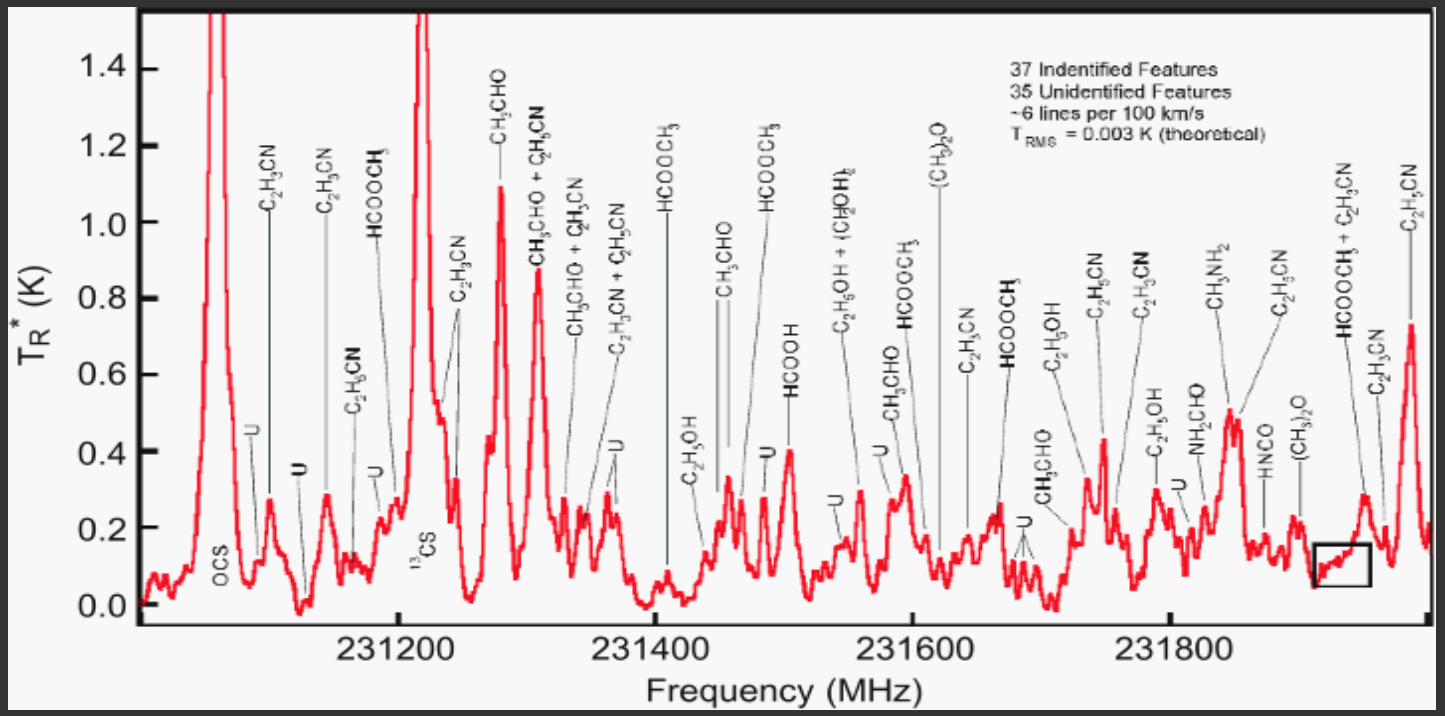
6 June 2018
NRAO Radio Astronomy and Physics Camp

Cosmology : History of the Universe



Looking farther away = Looking back in time !

Chemistry : We are all made of stardust

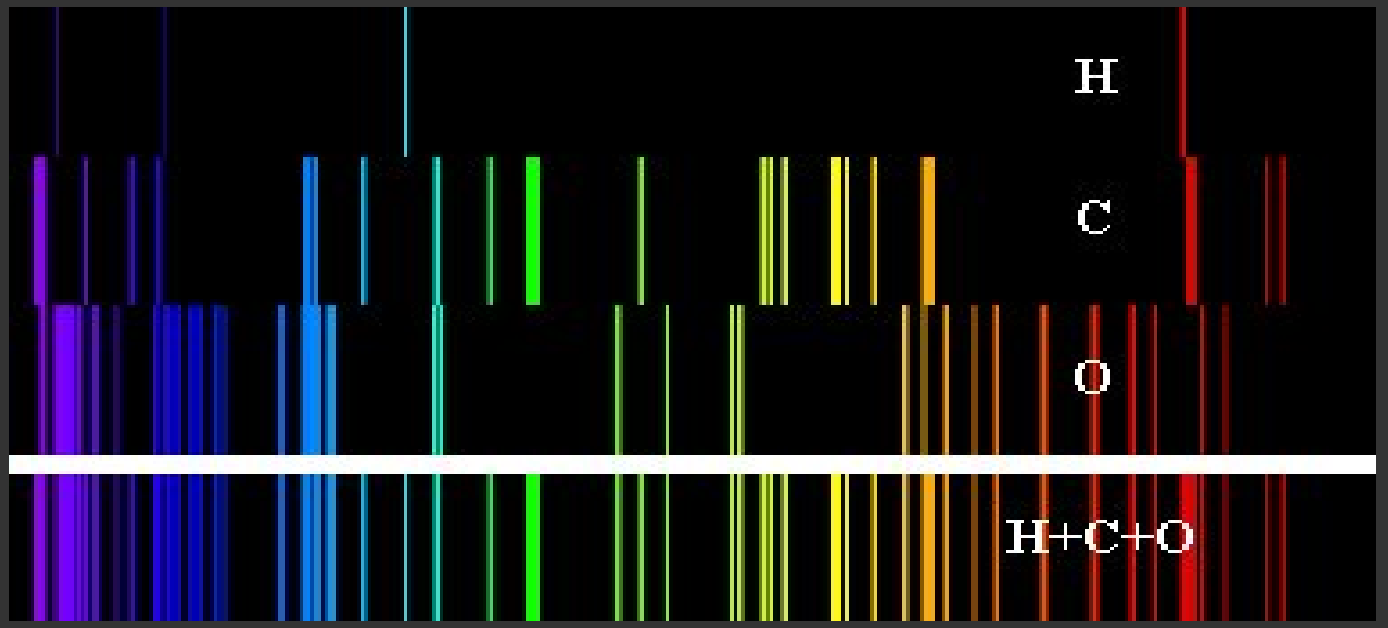


Measure the chemical composition of matter in space

Hydrogen, Carbon, Oxygen, Nitrogen

Organic molecules

=> Search for life !

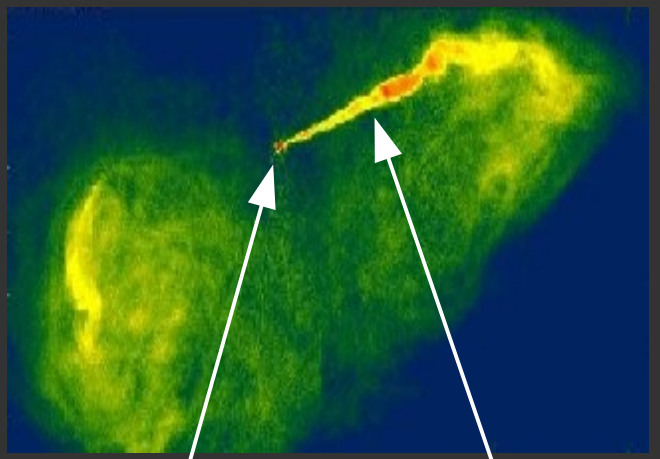


Extreme Physics in action

We can study phenomena that cannot be re-created on Earth in a lab.....

Gravitational Lens

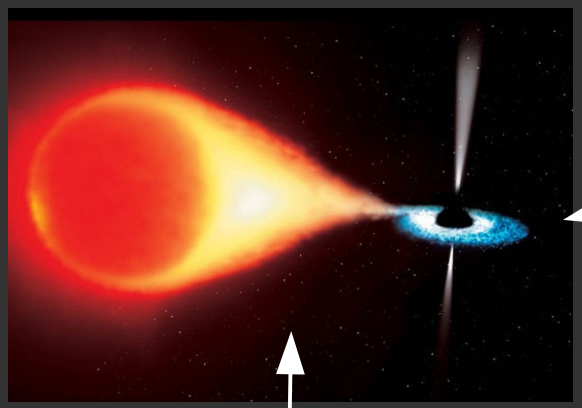
Life Cycle of a Star



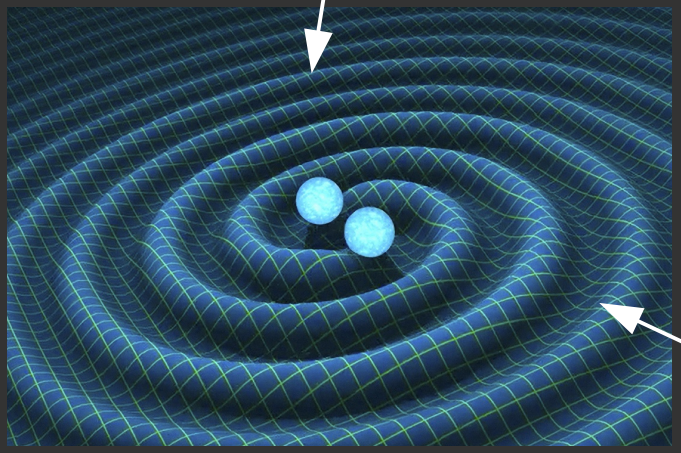
Black Hole

Jets of Plasma

Bending of light

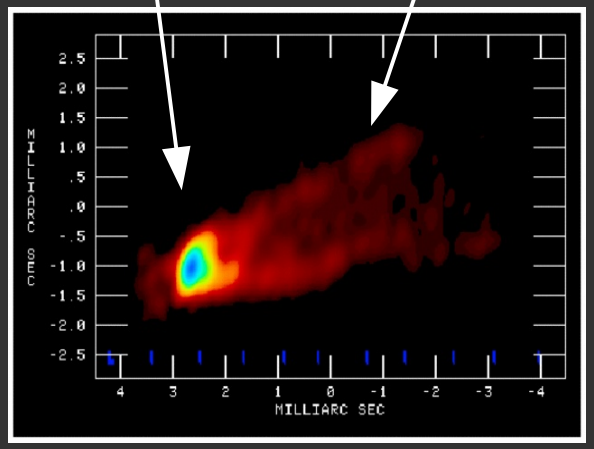


Binary stars

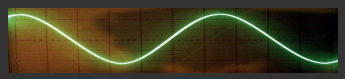


Spinning pulsars

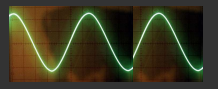
Gravity Waves



Take pictures all across the Electromagnetic Spectrum

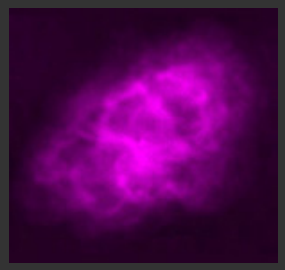


10^{6}	10^{4}	10^{2}	1	10^{-2}	10^{-4}	10^{-6}	10^{-8}	10^{-10}	10^{-12}	10^{-14}	wavelength (m)
ULF		Radio		Micro Wave	Infra red	Visible	Ultra violet	X-Ray		Gamma Ray	
10^{2}	10^{4}	10^{6}	10^{8}	10^{10}	10^{12}	10^{14}	10^{16}	10^{18}	10^{20}	10^{22}	frequency (Hz)

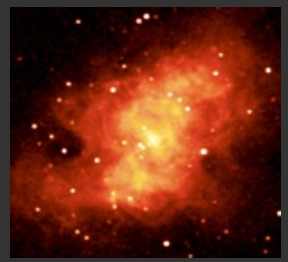


Objects can look different at different wavelengths

colours or shades of grey



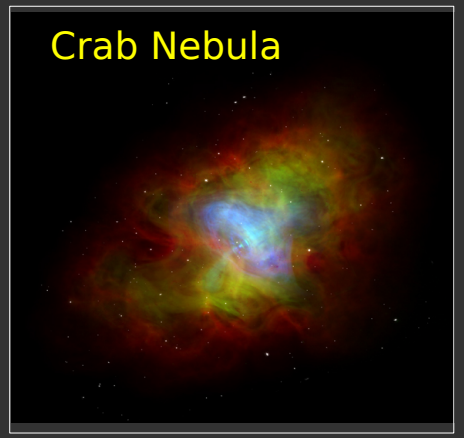
Radio



Infra-Red

Optical (visible)

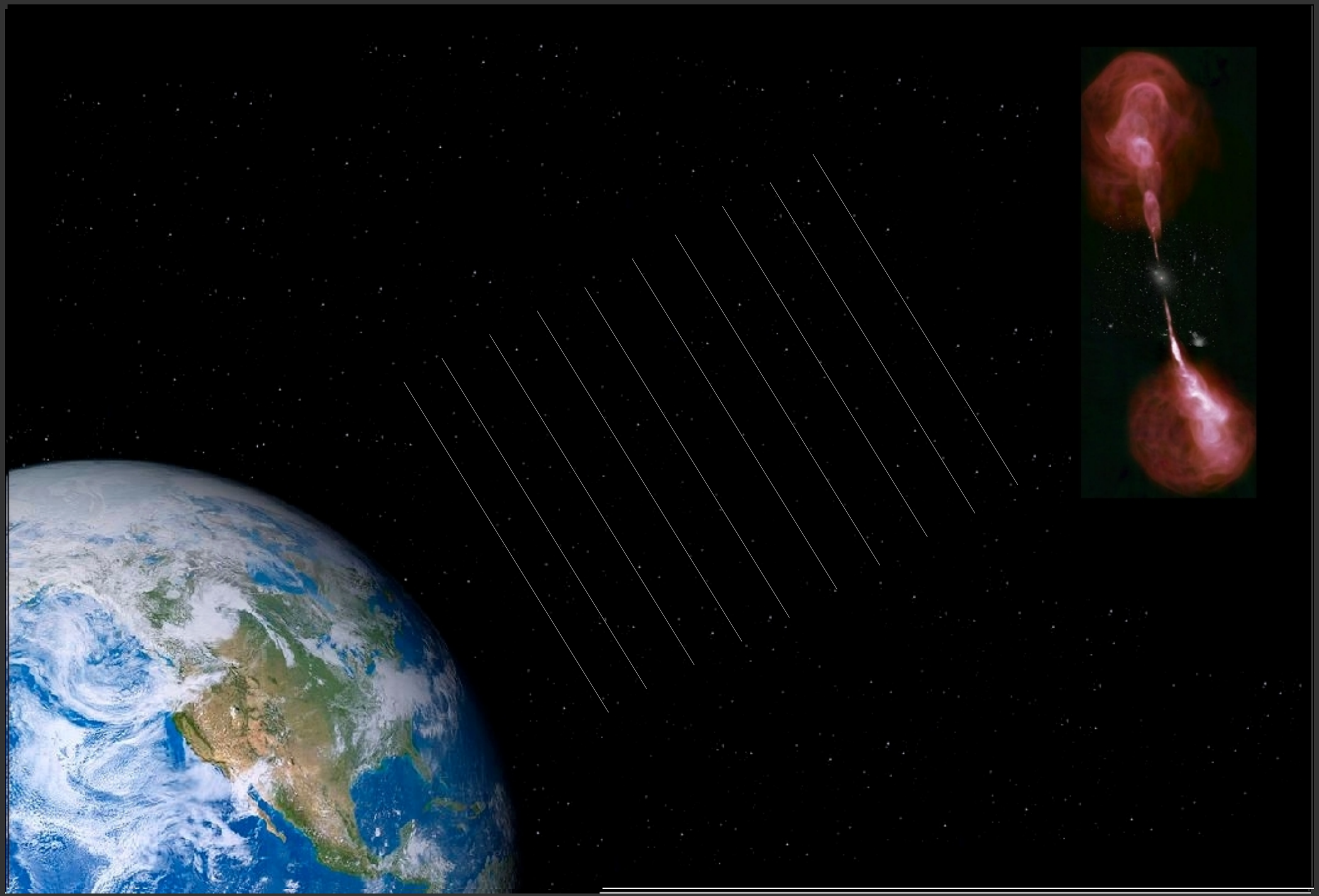
X-ray



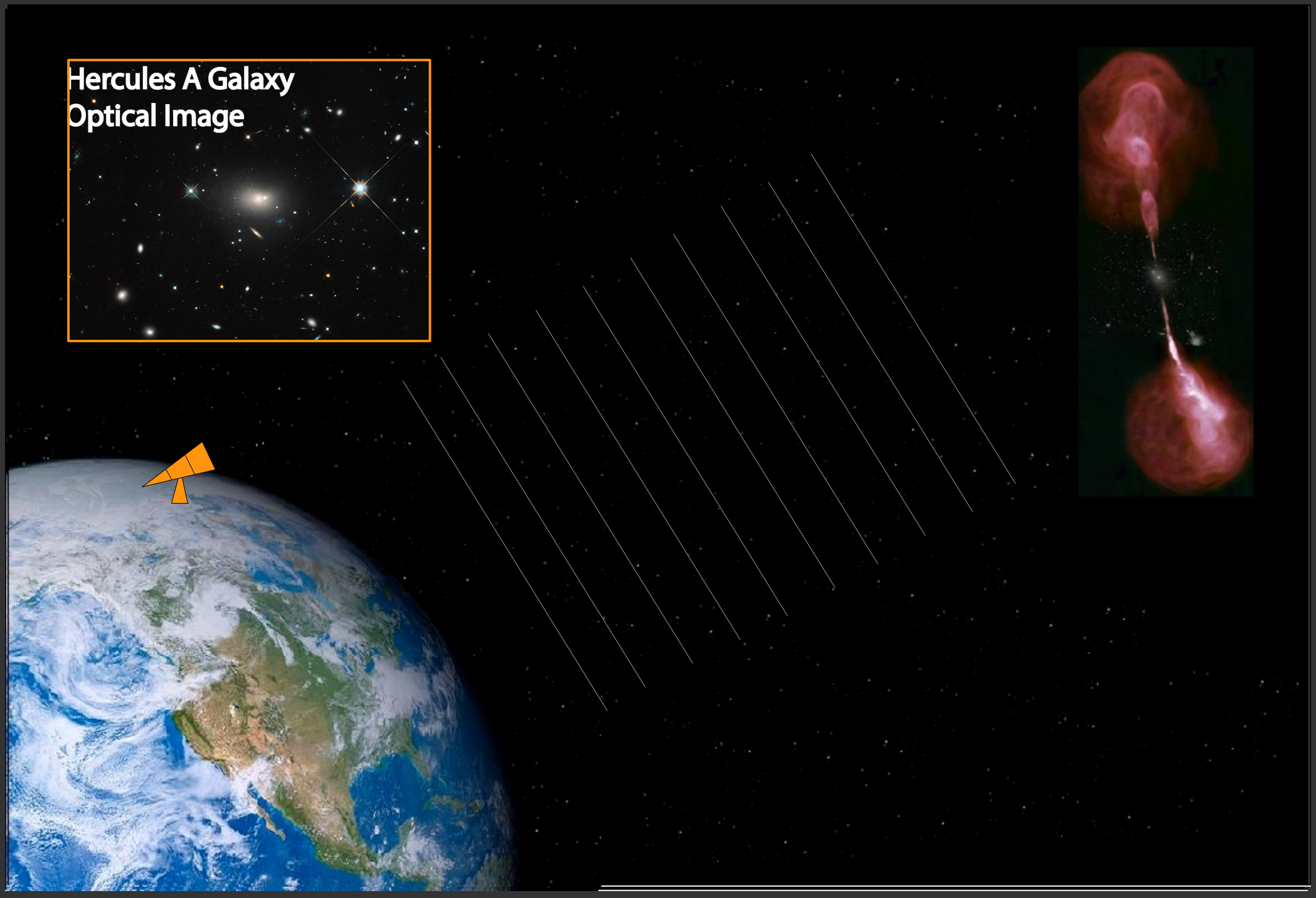
=> Want to make images at all wavelengths

..... with the same level of detail.

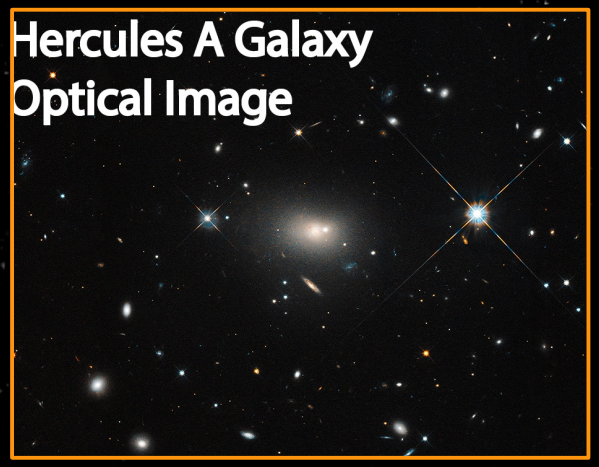
Telescopes and Images



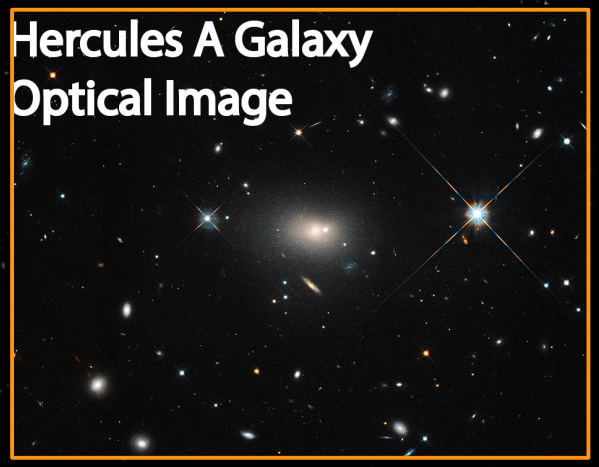
Telescopes and Images



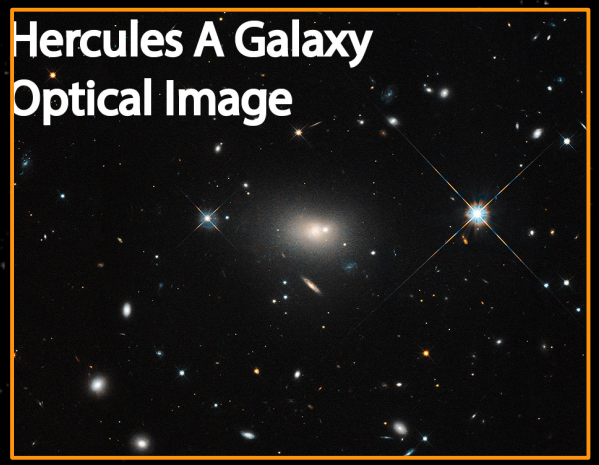
Telescopes and Images

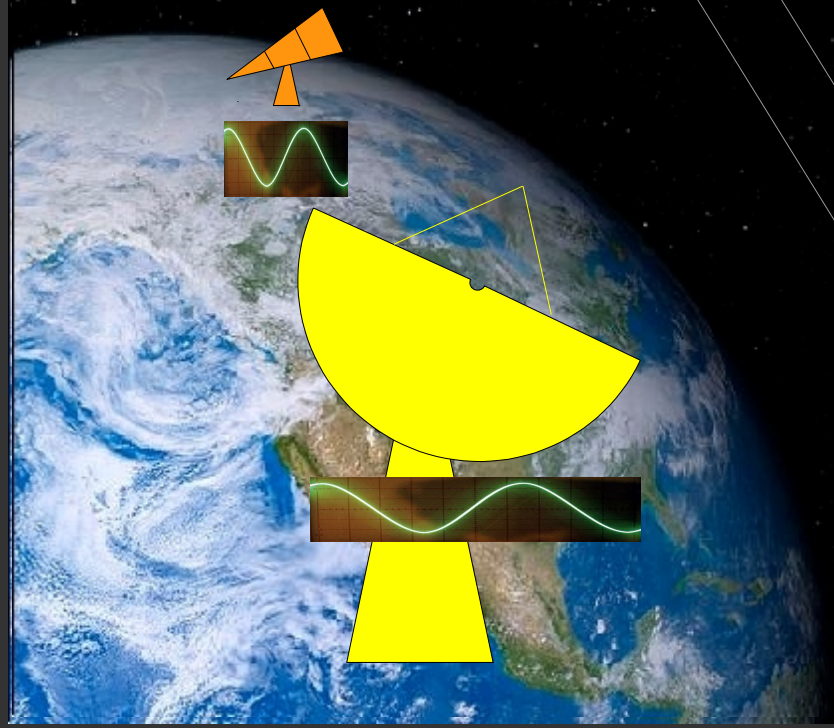


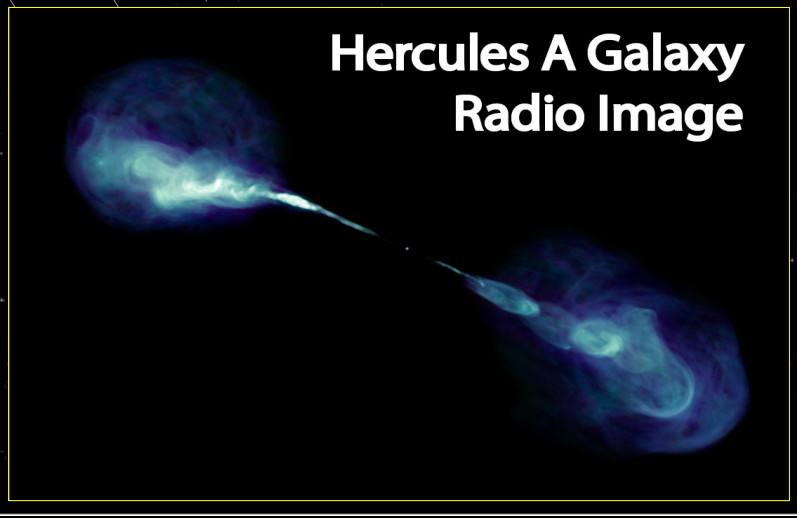
Telescopes and Images



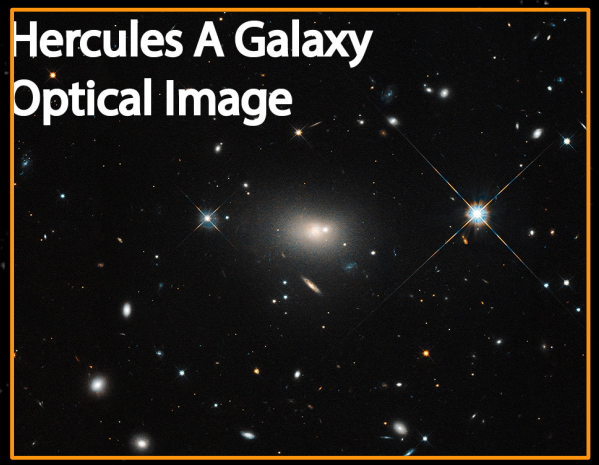
Telescopes and Images

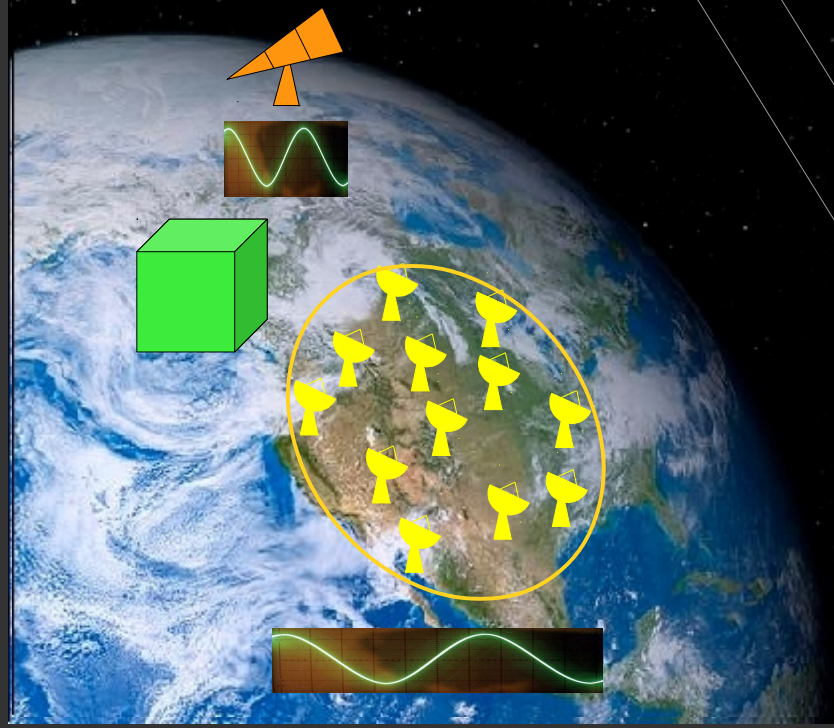


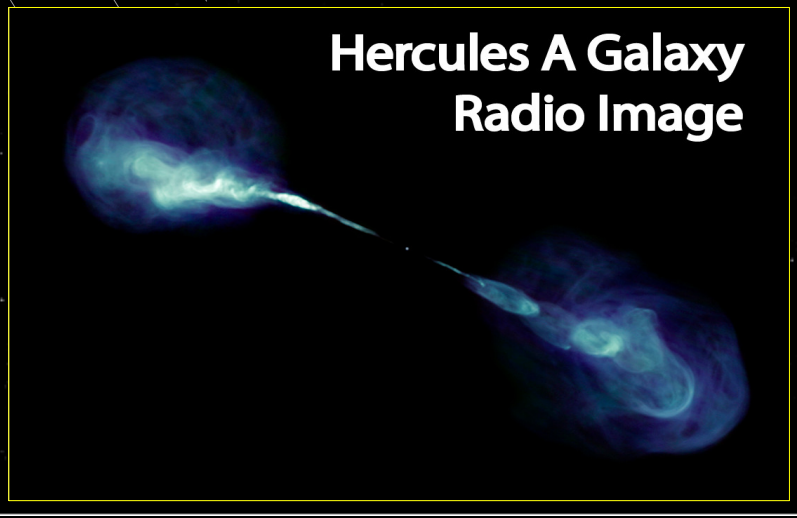




Telescopes and Images







Building a really large detector

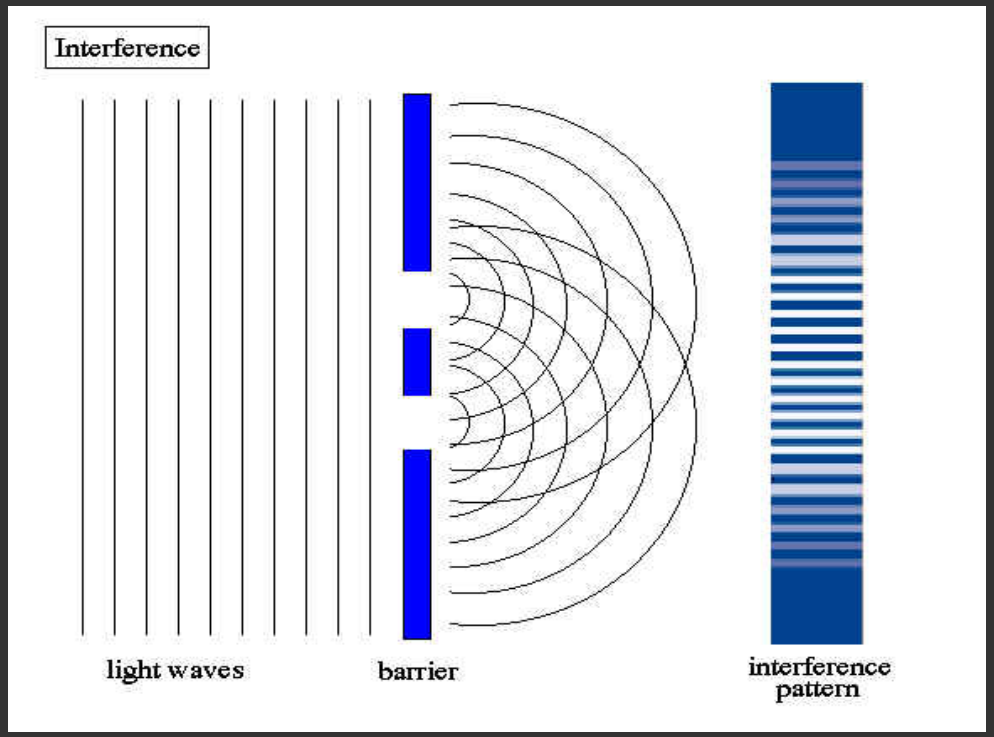
Artificially create a large “dish” using many smaller ones...

But ... this is not a real reflecting surface.....

So how do you make it behave like one ?

... imitate the Physics of a lens.

Measure interference fringes

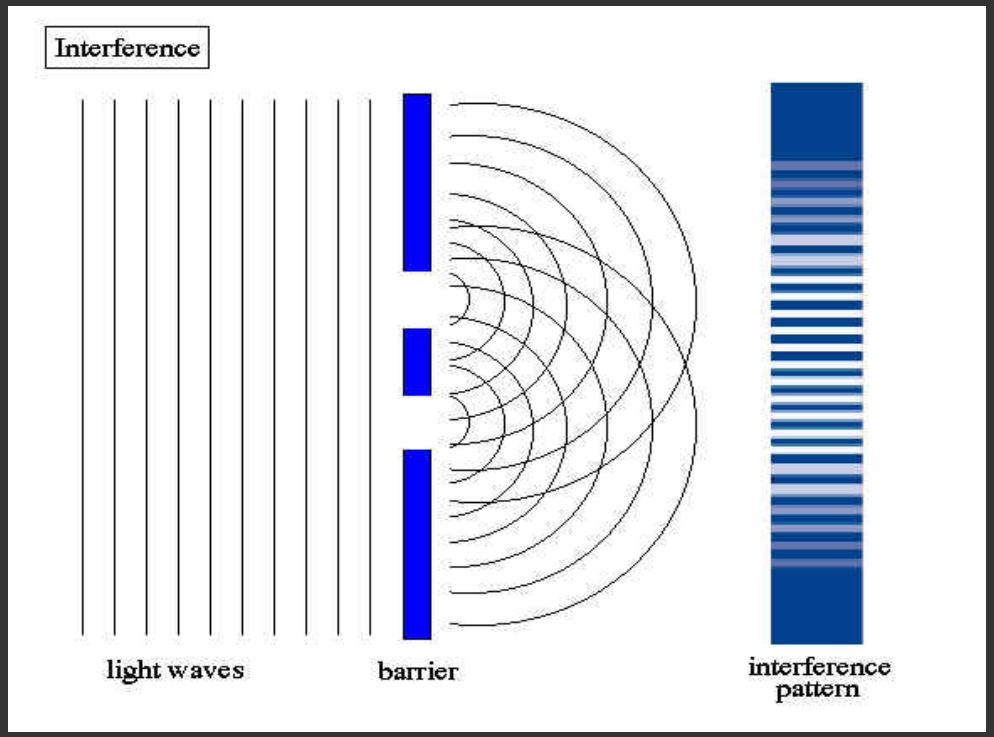


Young's Double-Slit Experiment

Light passing through a pair of slits (or holes) makes ‘fringes’.

Distance between slits controls the width of the fringes

Measure interference fringes



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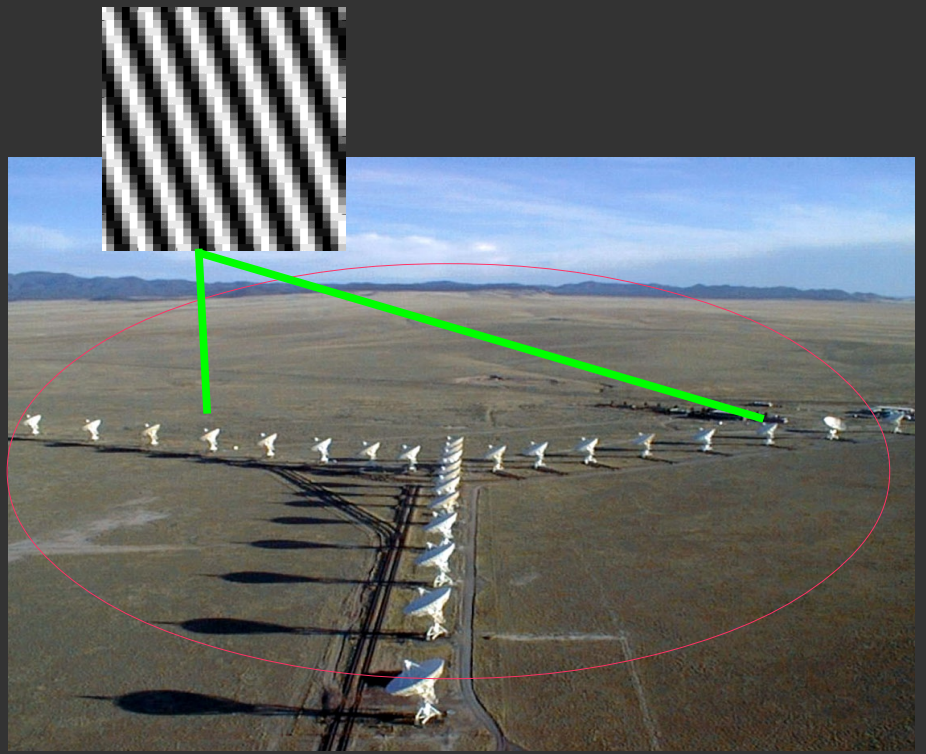
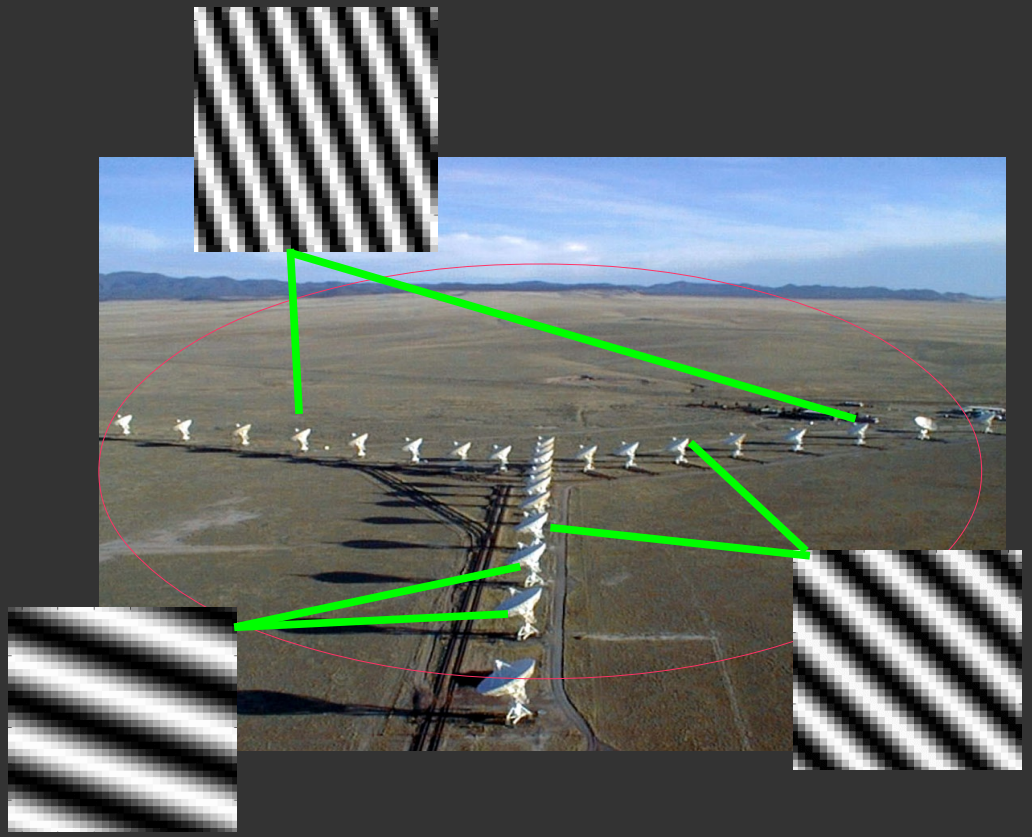


One dish == One slit

=> Each pair of antennas measures a different 2D fringe.

Make the Image

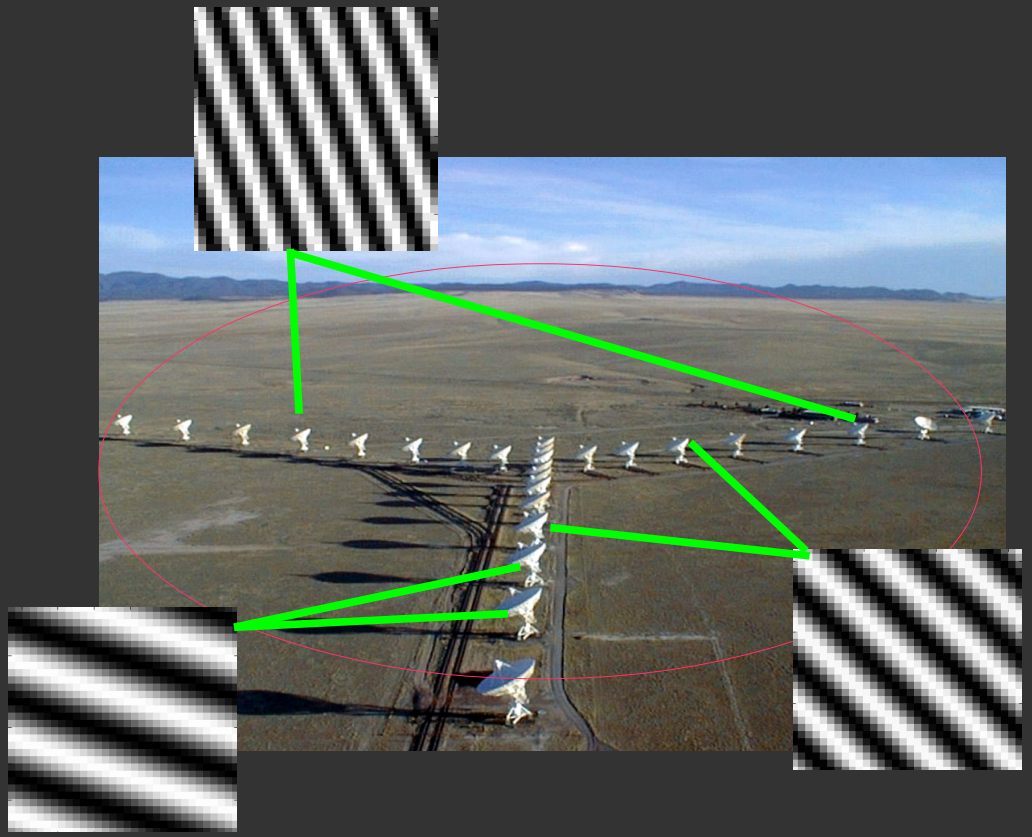


Measure fringes from all pairs of antennas

N antennas

=> N(N-1)/2 pairs

Make the Image



Measure fringes from all pairs of antennas

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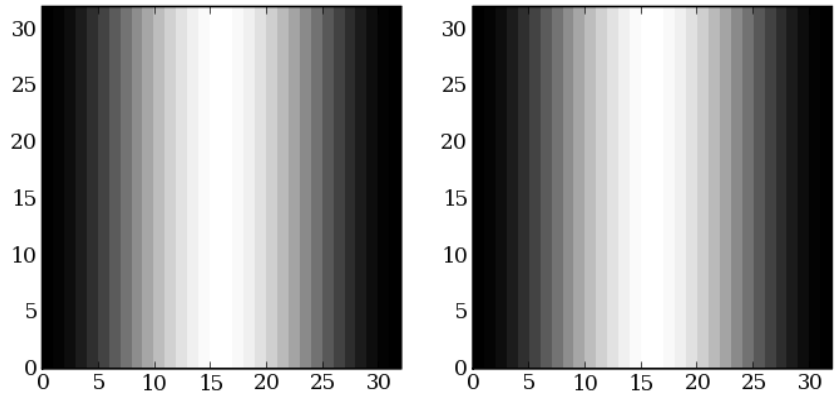


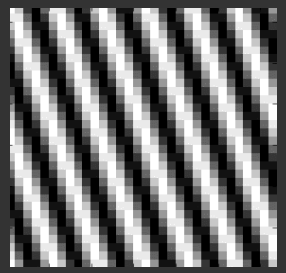
Build an image by adding all the fringes together.

2D Fourier transform :
Image = sum of cosine 'fringes'.

Measuring each 'fringe'

Each Pair of Antennas :

=> Measures parameters
of one 2D “fringe”



Amplitude, Phase, Orientation, Wavelength

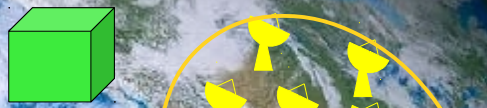
Radio Interferometry in practice

Build a giant camera....

- Follow the Physics of how a lens works.

- Measure and add up interference fringes.

Data Analysis



+ Many small telescopes

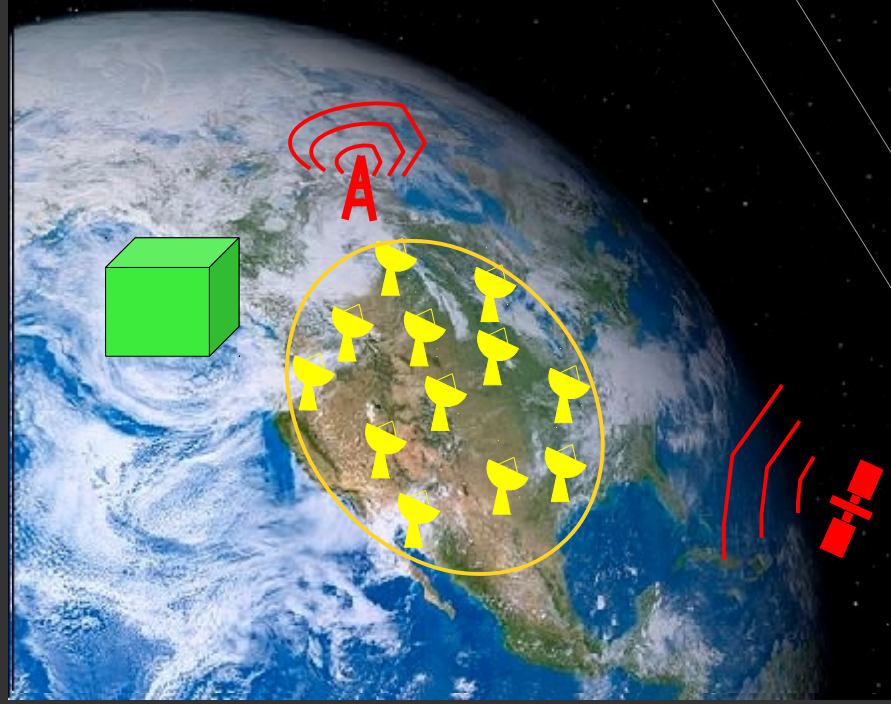
+ Electronics

+ Computers and Software

Data Analysis - Step 1

Radio Frequency Interference

Editing : Remove bad data



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Radio Frequency Interference

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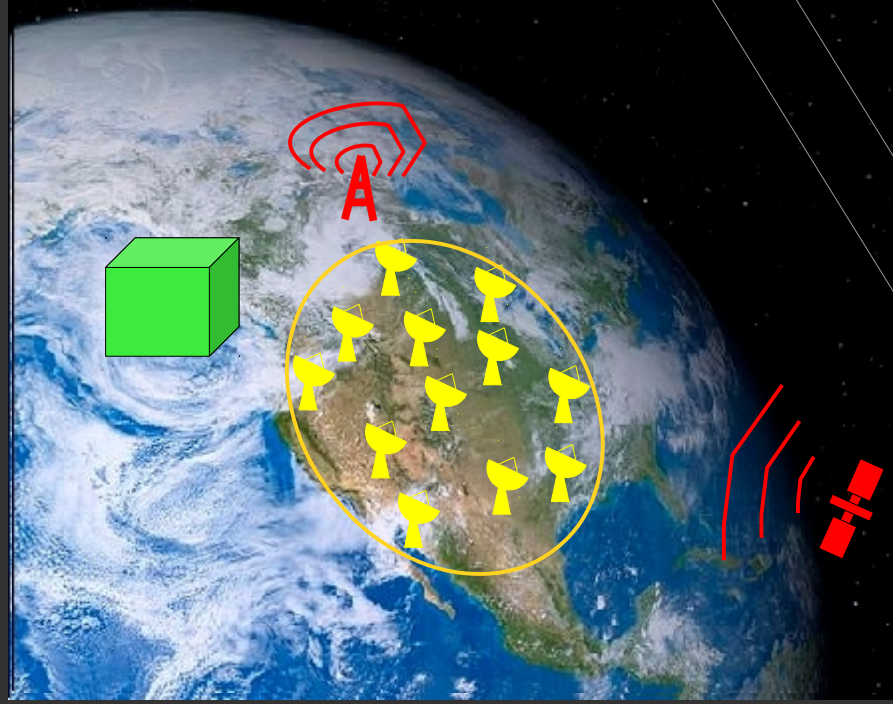
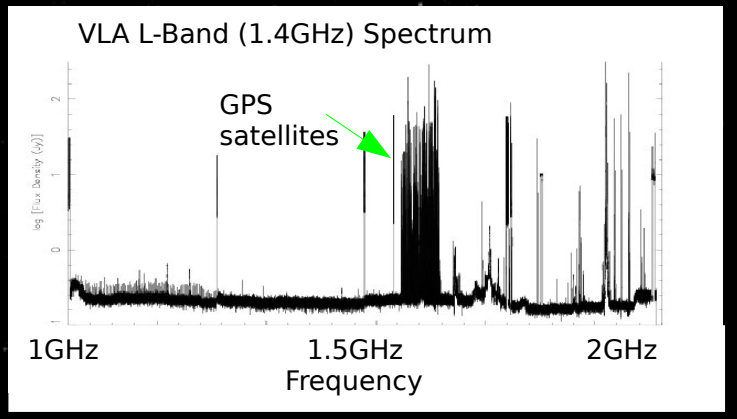
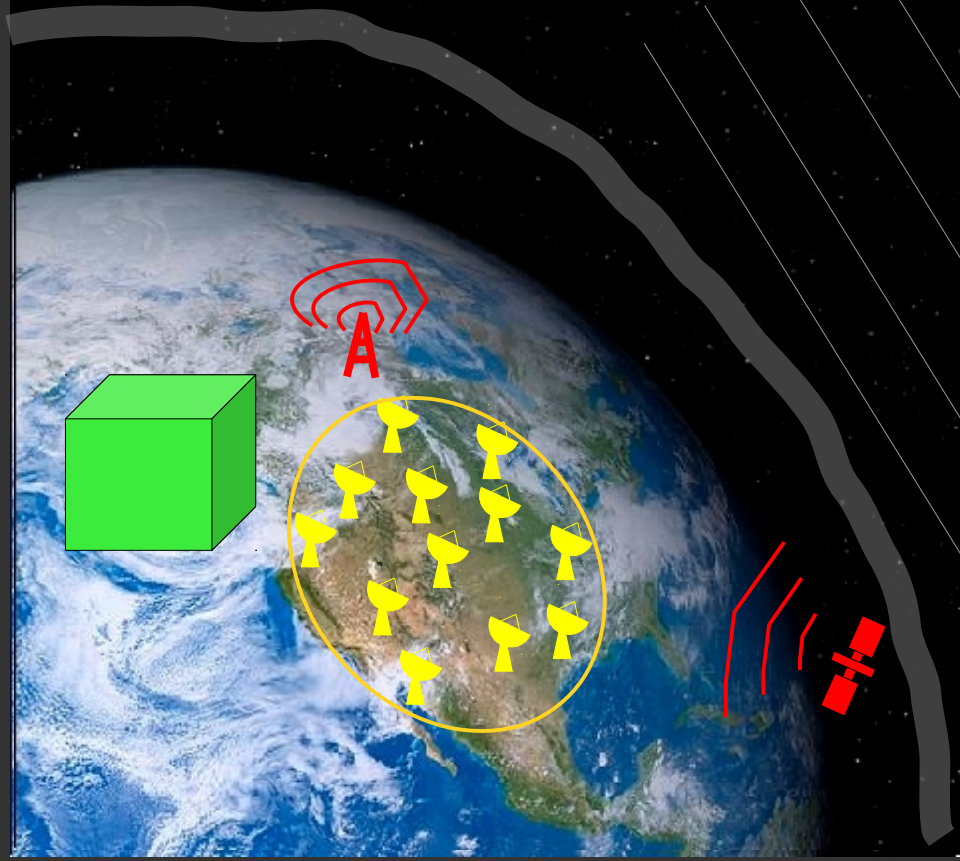




Data Analysis – Step 2

Signals measured at each antenna are distorted
(electronics, refraction though ionosphere, weather….)

Calibration : Undo distortions



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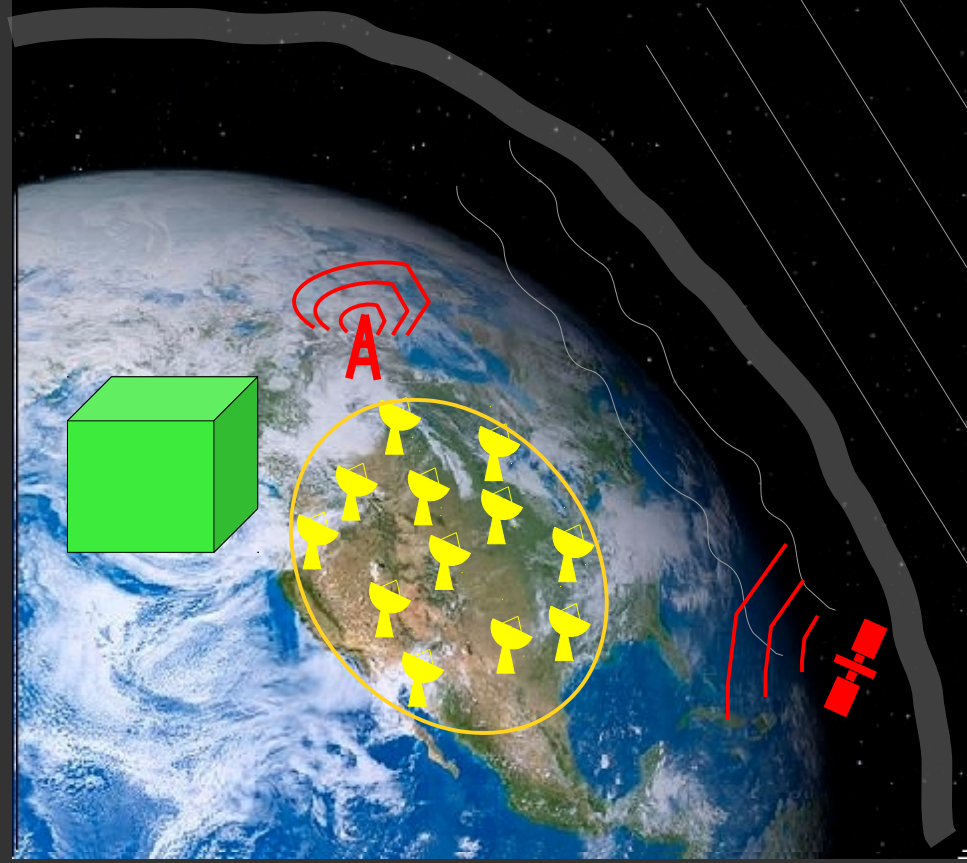
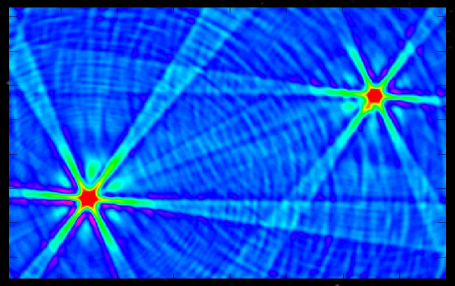
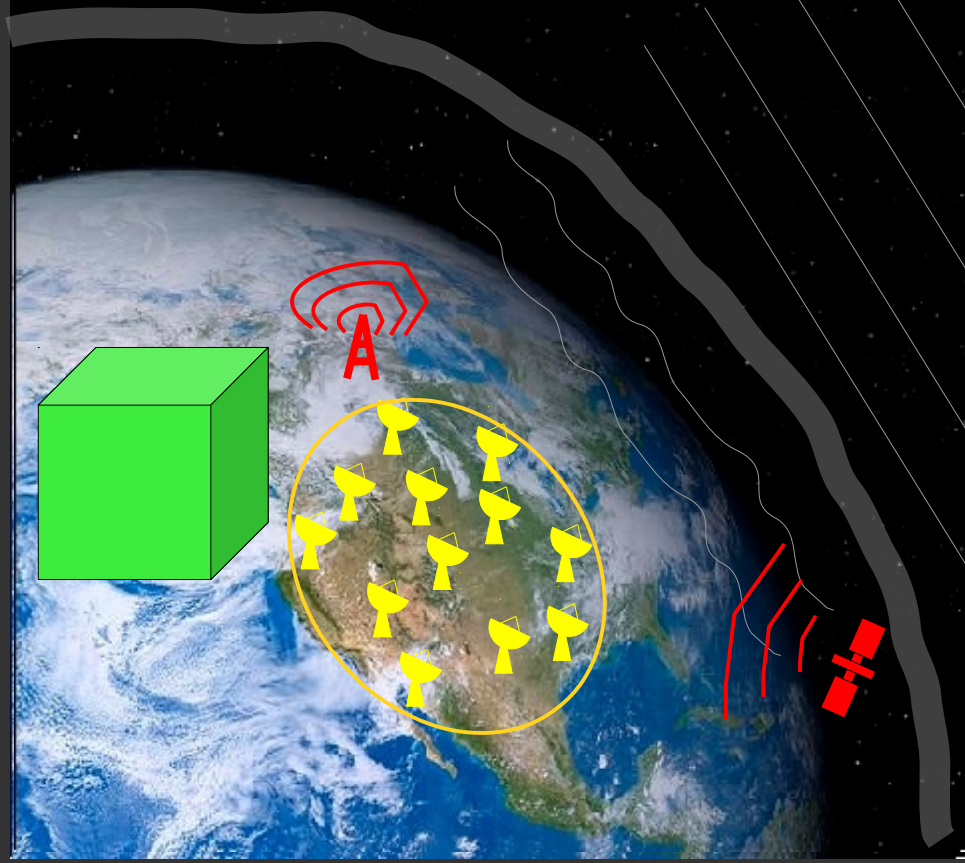


Data Analysis – Step 3

Make the image : Add all the fringes together

Only some fringes are measured.





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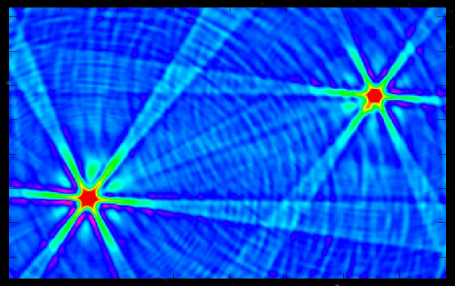
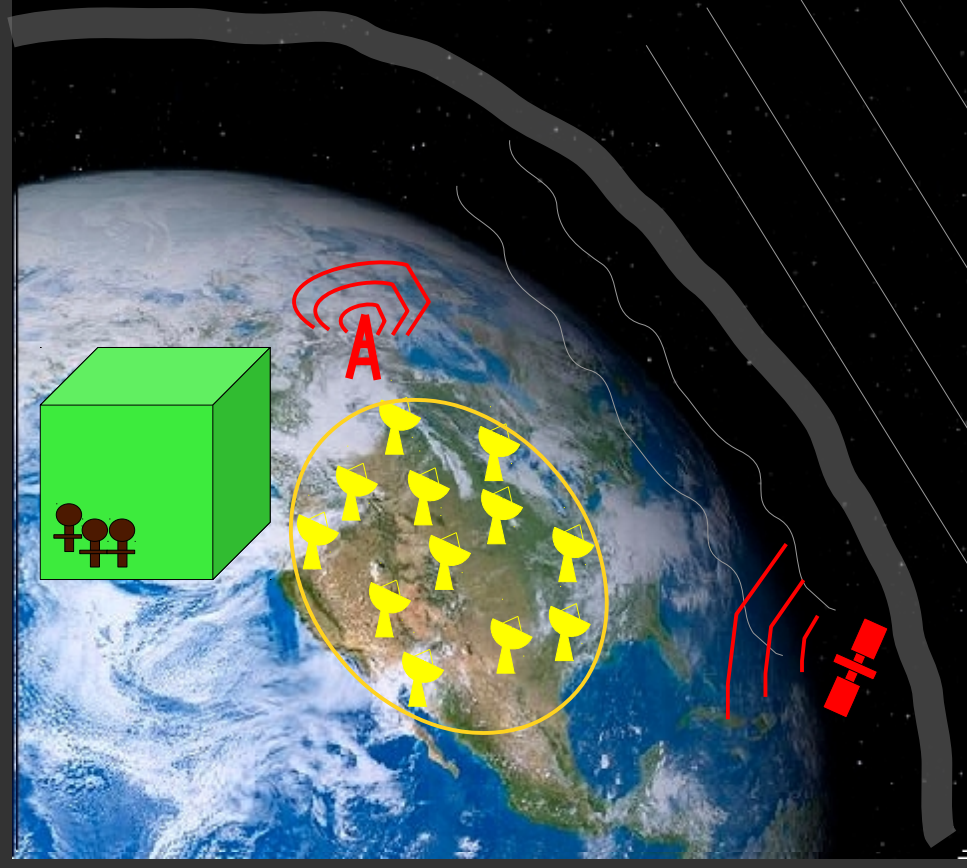
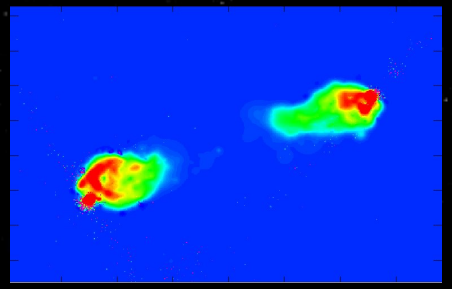


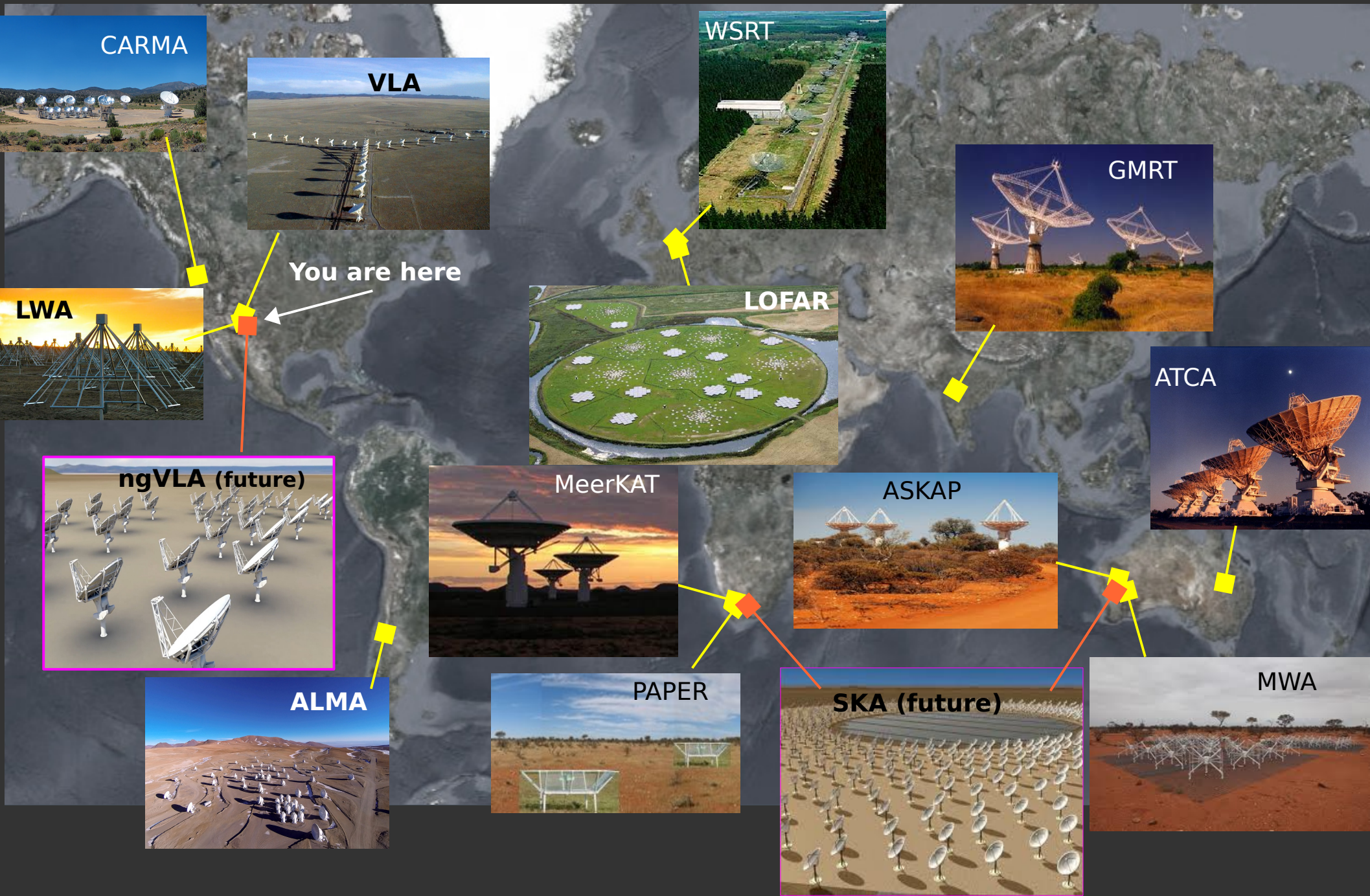


Need to estimate the unmeasured fringes

Image Reconstruction



Radio telescopes of the world (now + future)



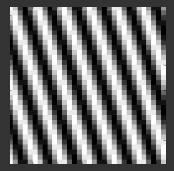
Things to learn in school and college

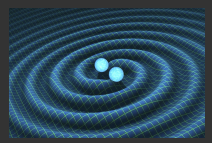
Physics

Optics

Computer Programming

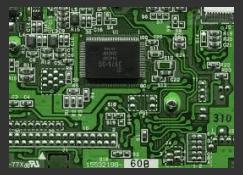
Math





Calculus

Electronics, Circuits



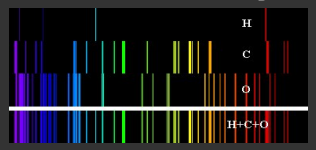
Data Analysis

Algebra

Construction

Networks

Chemistry



Internet of things

Antennas

Signals

Artificial Intelligence

Science experiments

Radios

Photography

Solar Power

Solving puzzles

This is fun !