Radio Astronomy: an introduction

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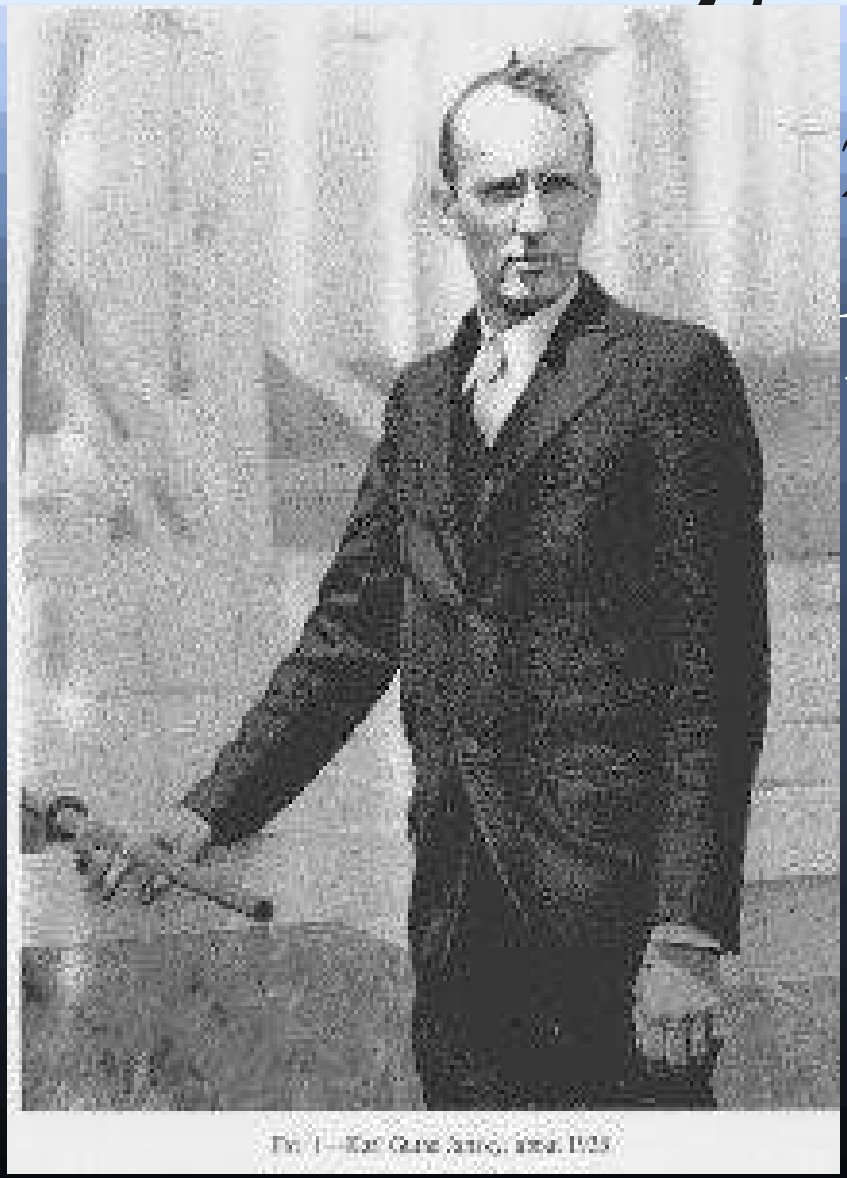
Good reasons NOT to do astronomy with radio waves

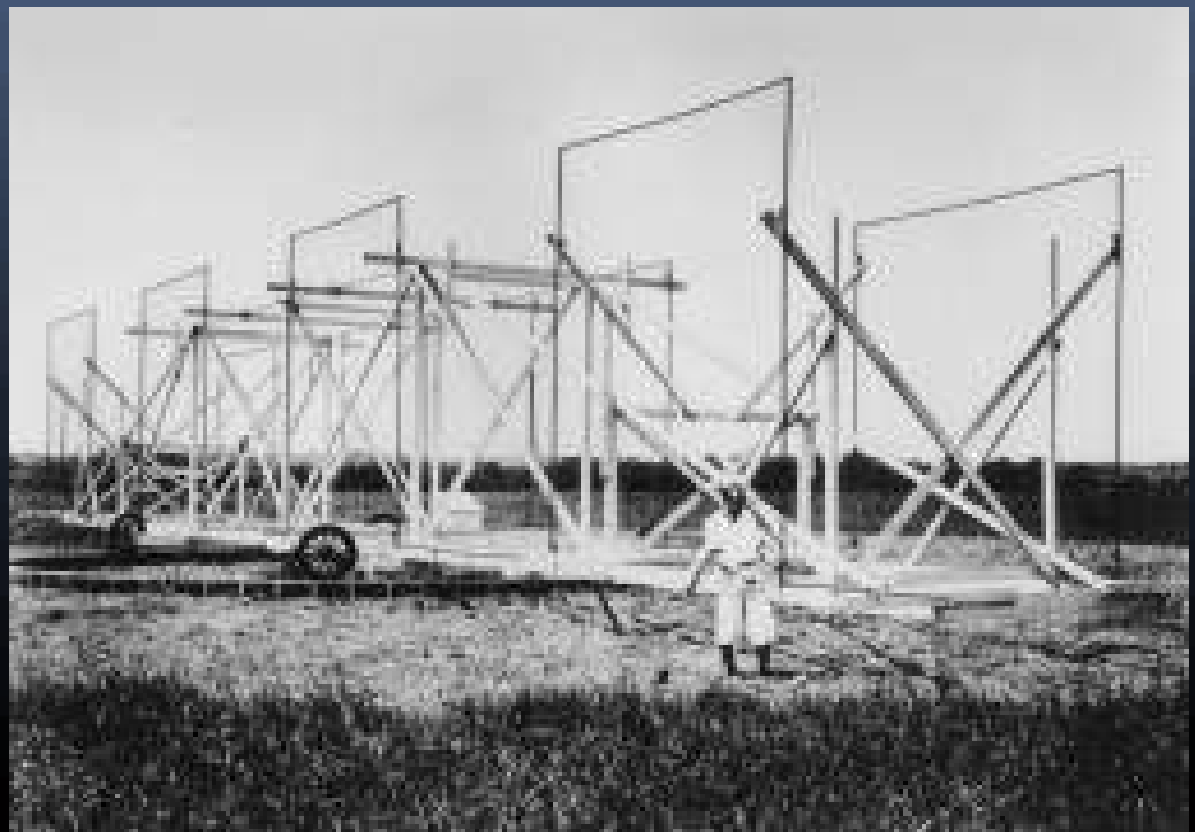
- Astronomy is all about stars which are at 1000's of degrees and radiate in the visible region
- For radio waves, say at 1.35 cm, 22 Ghz, , the corresponding temperature is one degree Kelvin, who wants to look at such cold stuff?
- The power in radio for the Sun would be 10 e-12 of the total
- To make up, one would need a large solid angle but the space between the stars is empty, anyway

Radio waves from the Milky Way
Karl Jansky, Bell Labs, USA, 1932

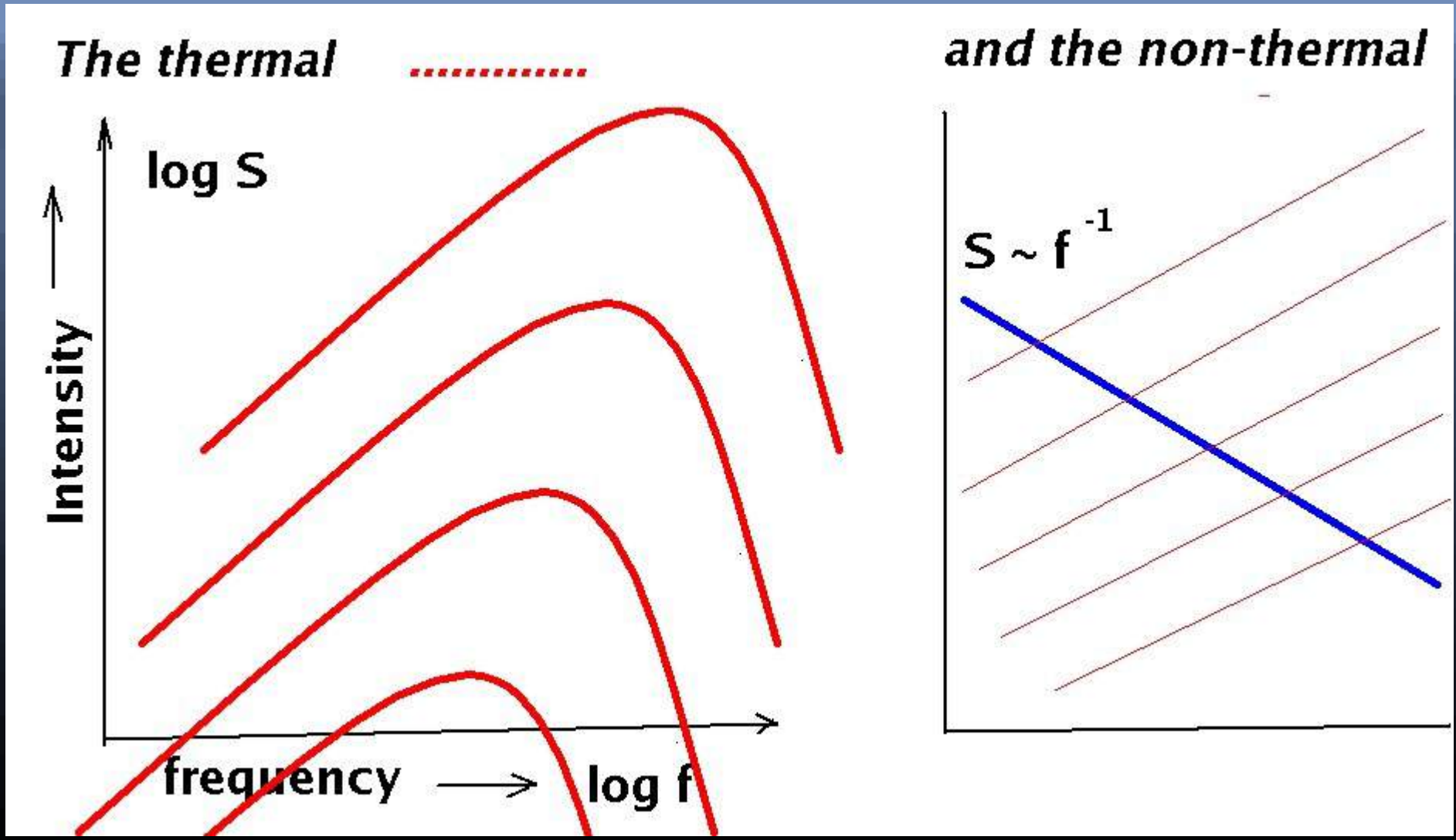


wavelength 14.5 m , frequency 20 MHz

1 Jansky = 10 e - 26 Watts/metre^2/Hertz

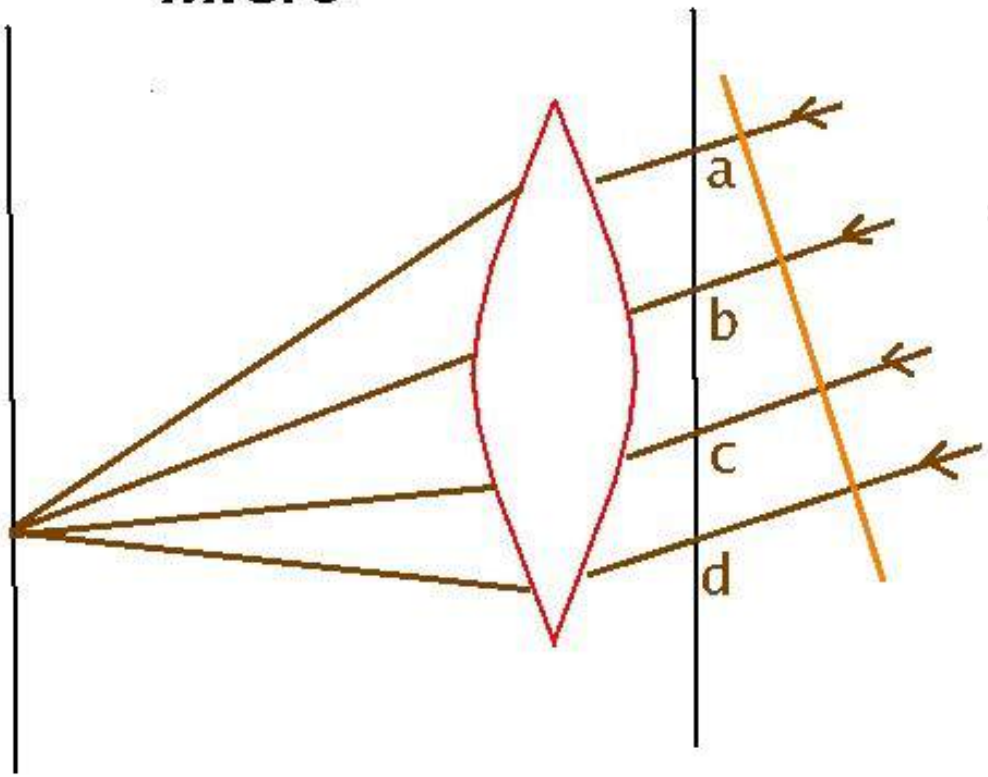


Cosmic radio waves are not like black body radiation!



Images are made of correlations: Abbe, Zernike, Michelson....

All tele micro scopes are interferometers



$$E = a + b\,e^{-i\phi} + c\,e^{-2i\phi} + d\,e^{-3i\phi}$$

= *Fourier transform of input field*

$$I = |E|^2 = a\,a^* + b\,b^* + \ldots\ldots$$

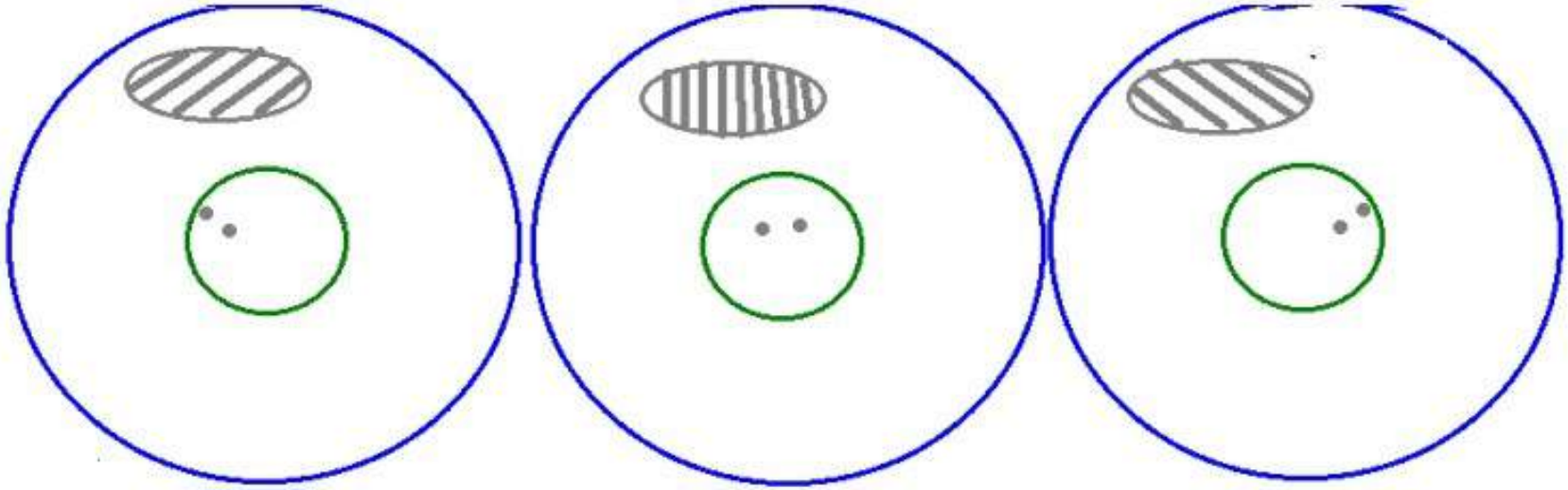
$$+ a\,b^*\,e^{i\phi} + a\,c^*\,e^{2i\phi} + \ldots\ldots$$

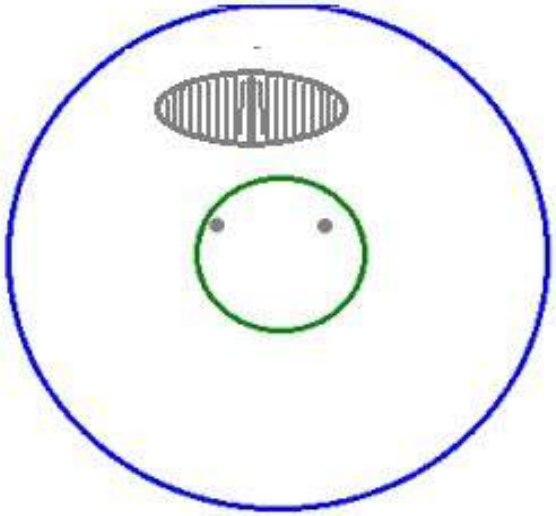
$$+ b\,d^*\,e^{2i\phi} \ldots\ldots\ldots\ldots$$

Fourier transform of input correlations

Large telescopes from small: Ryle, Cambridge,1960

The geometry of Earth rotation aperture synthesis.....





.....and the algebra

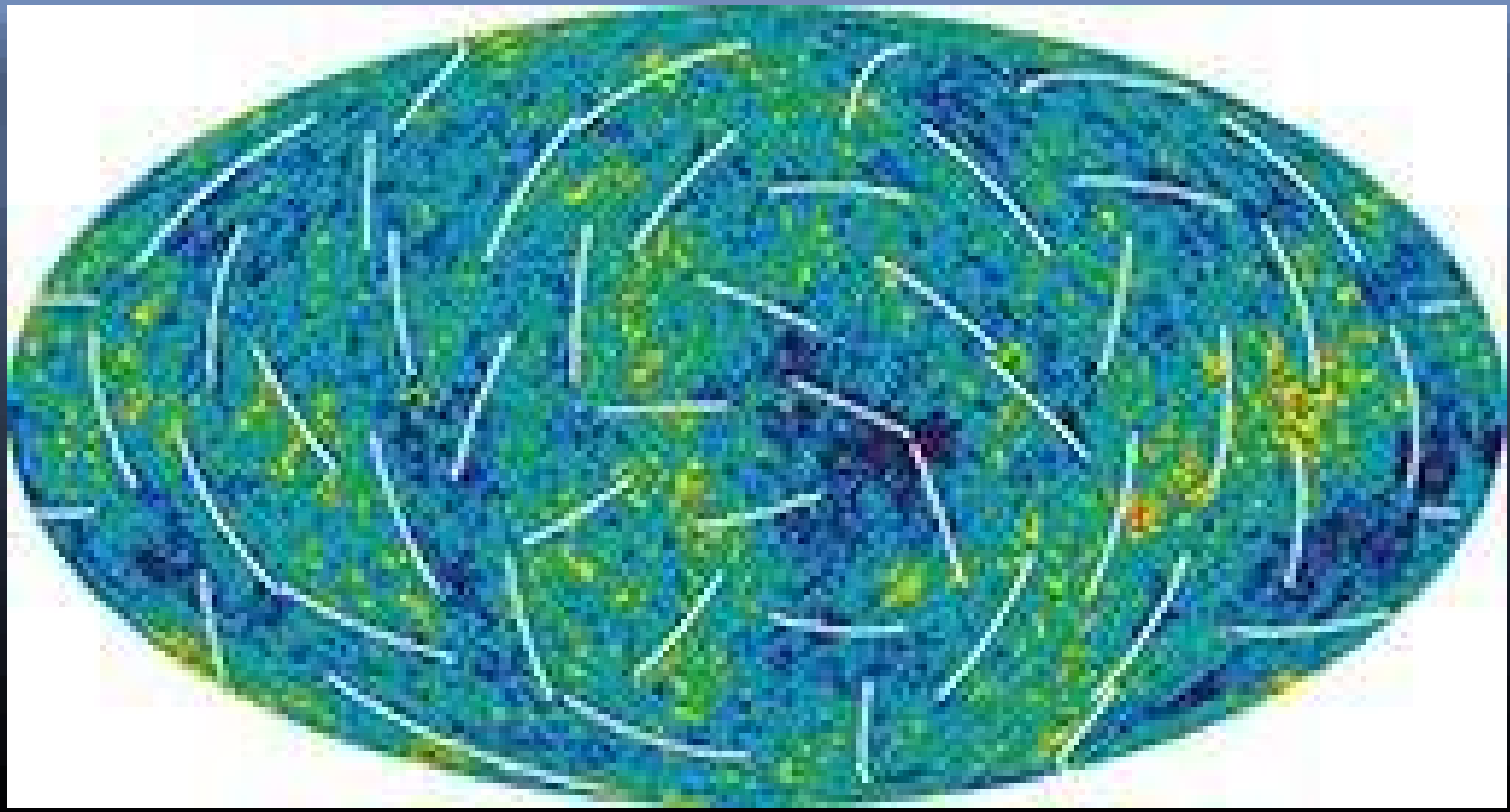
$$E(x,y) = \sum \tilde{E}(k_x, k_y) \exp\left(i (k_x x + k_y y) \right)$$

$$\left| \tilde{E}(k_x, k_y) \right|^2 = \text{I.F.T of} \left\langle E^*(x+u, y+v)\, E(x,y) \right\rangle$$

The Very Large Array: NRAO, New Mexico, USA

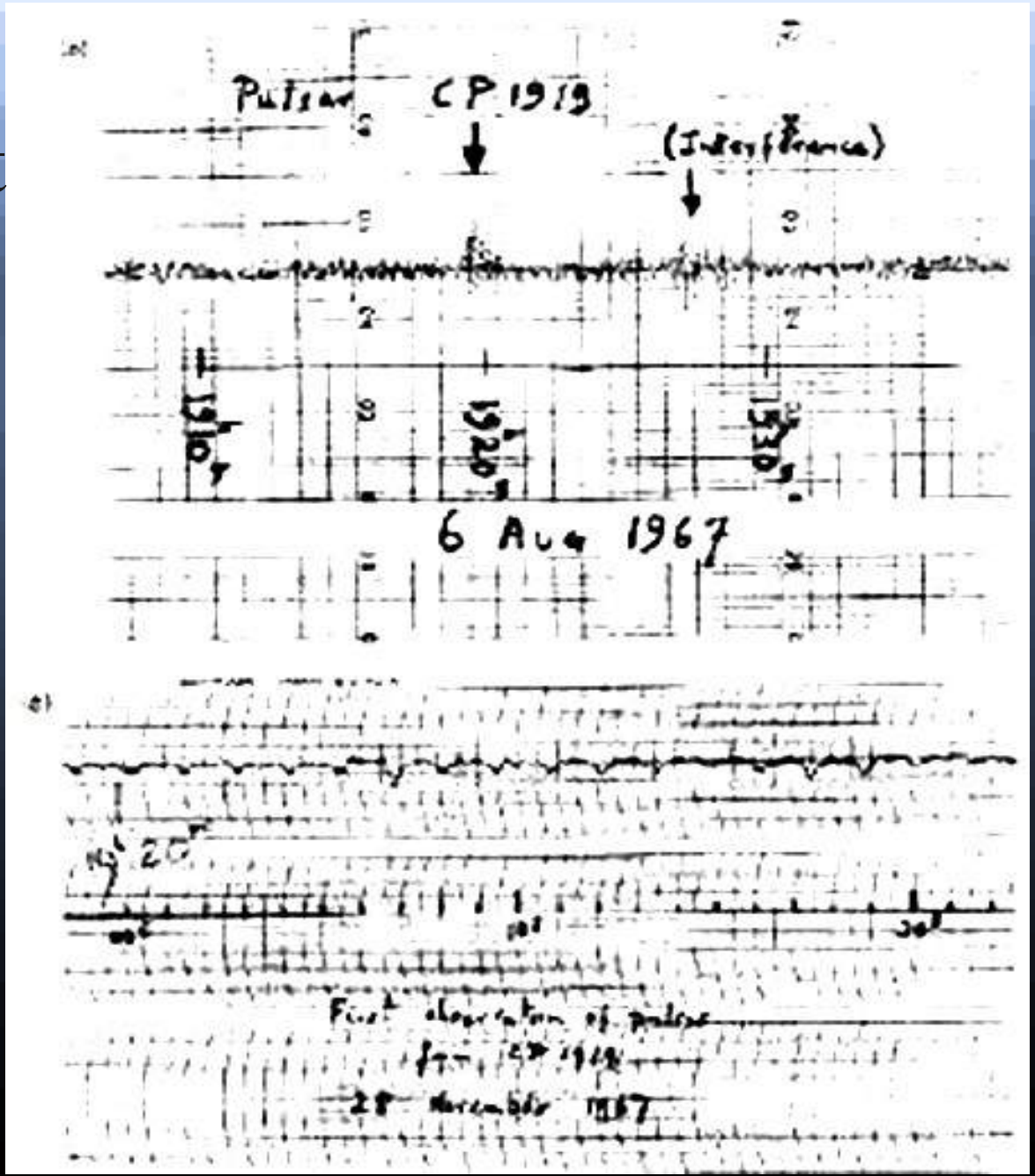
Bell Labs, 1965 – the Universe is a black body at 2.7 degrees Kelvin..almost

COBE and WMAP show temperature variations and polarisation of the radiation



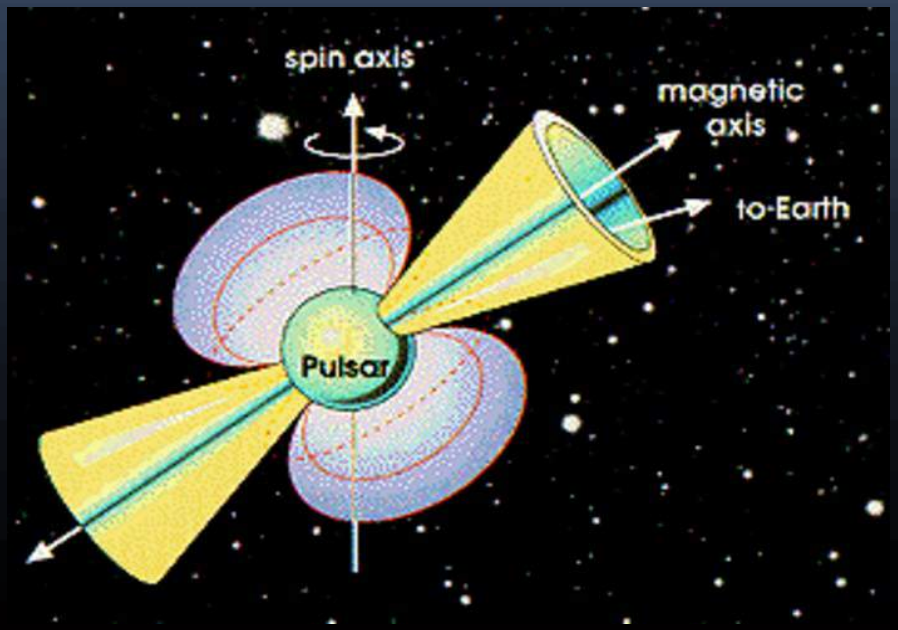
The little green men of 1967

Jocelyn Bell-(Burnell) as a research student at Cambridge



Radio pulsars – the crash course

spinning neutron stars 20 km across with coherent radio beams fit the data



- being braked by their magnetic dipole moments
- can spin upto 0.6 kHz!
- timing their pulses helps us track their movements to about 1 km accuracy

The importance of timing pulsars

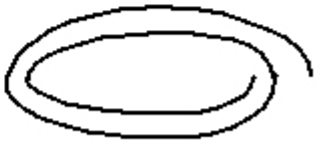
By accurate (sub microsecond) pulse timing, at earth, one measures

orbital parameters: period
eccentricity, projected axes

Precession

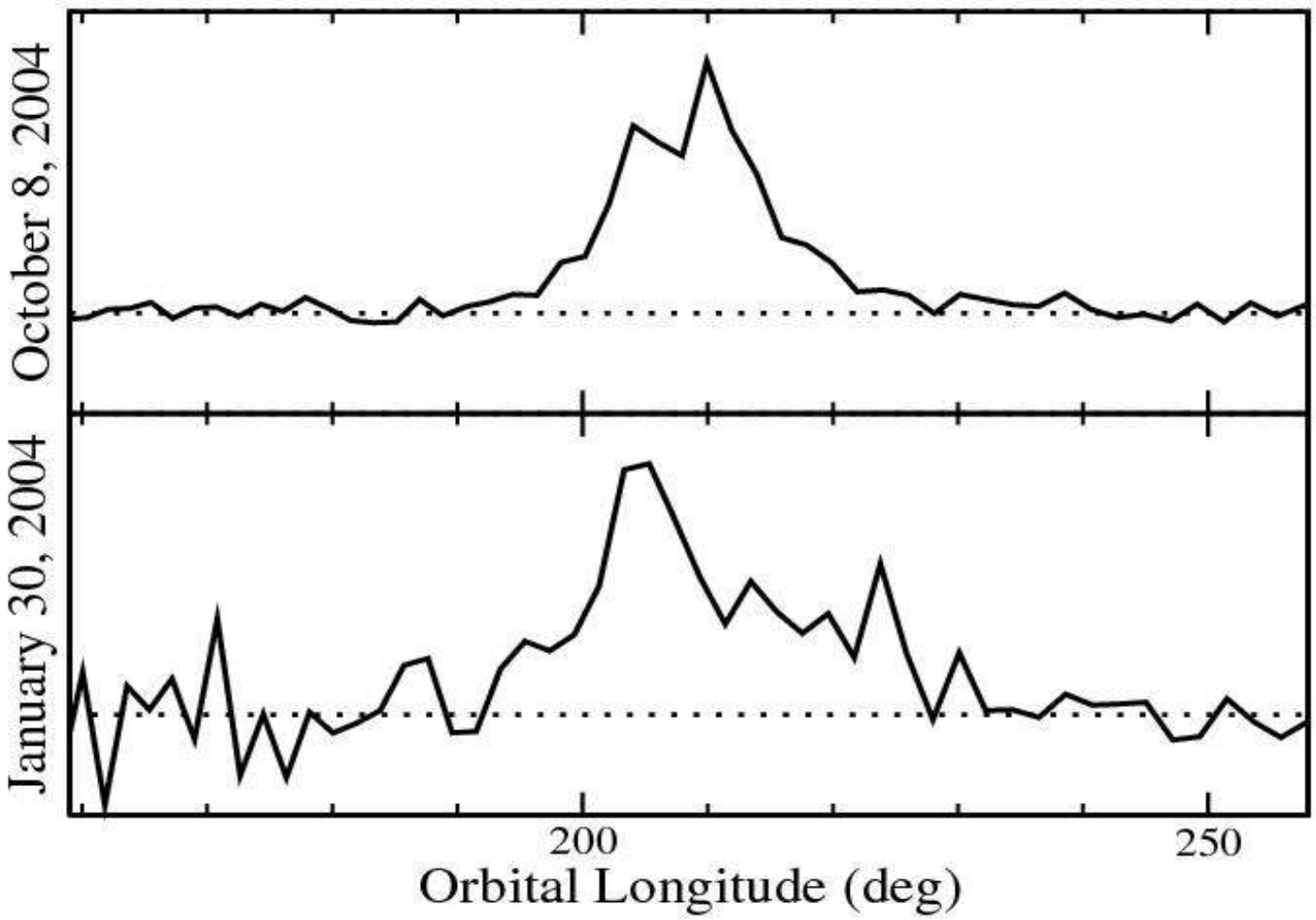
gravitational time delay

Inspiral

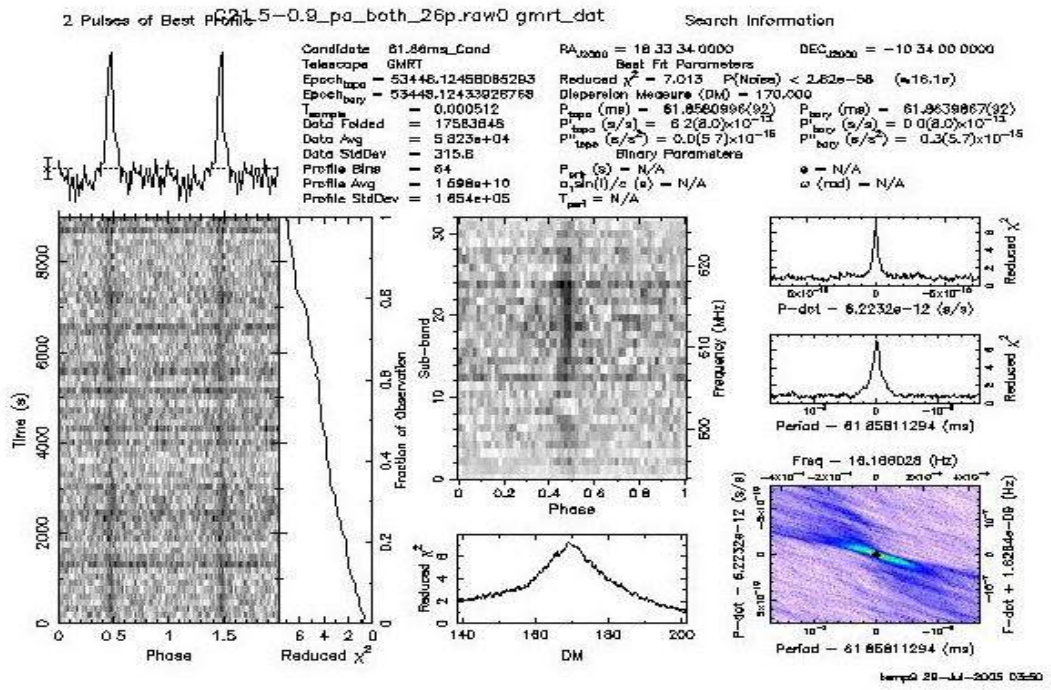


0737 -3039 A tale of two pulsars

B.C.Joshi
2004



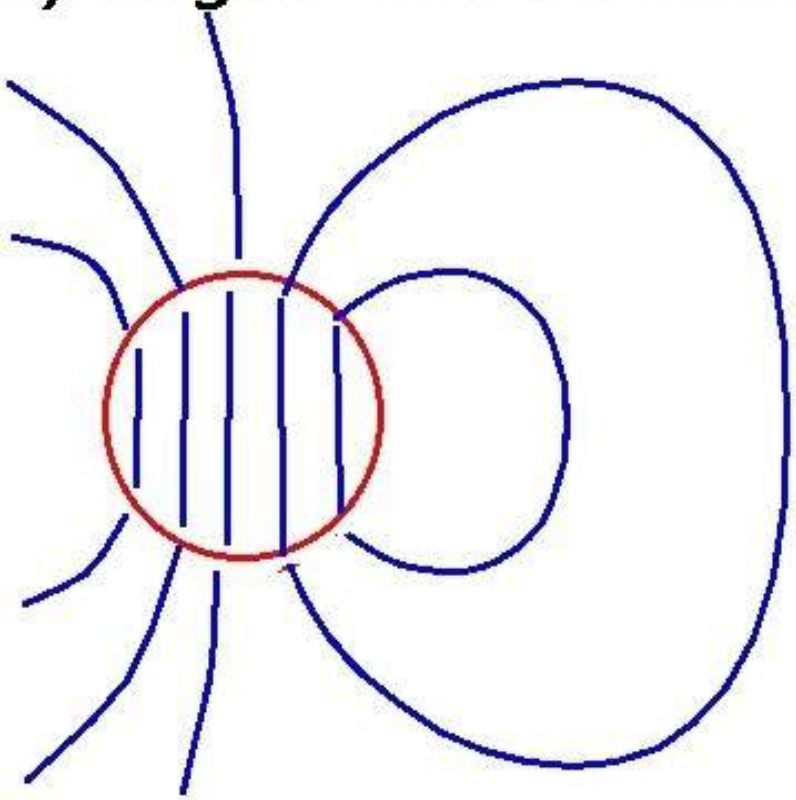
The Crab's older brother 1833 -1024



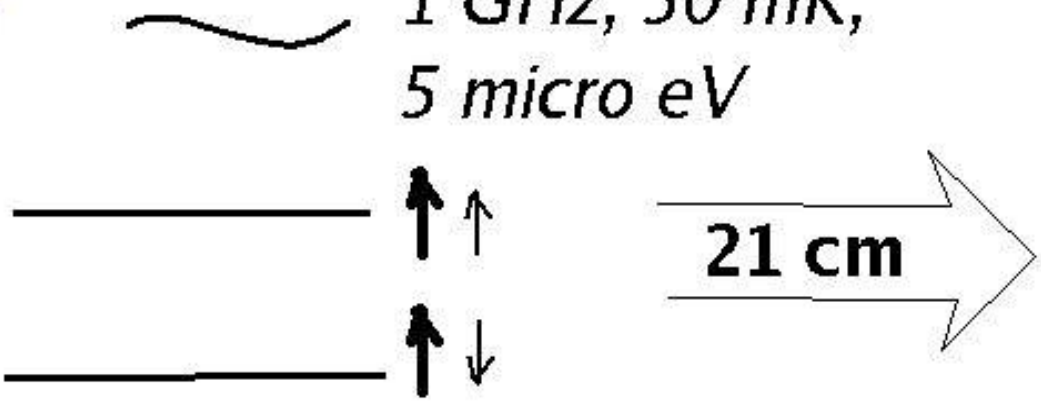
Gupta, Green Mitra, Acharya 2005

One planned discovery – van de Hulst, Oort, Netherlands, 1940's

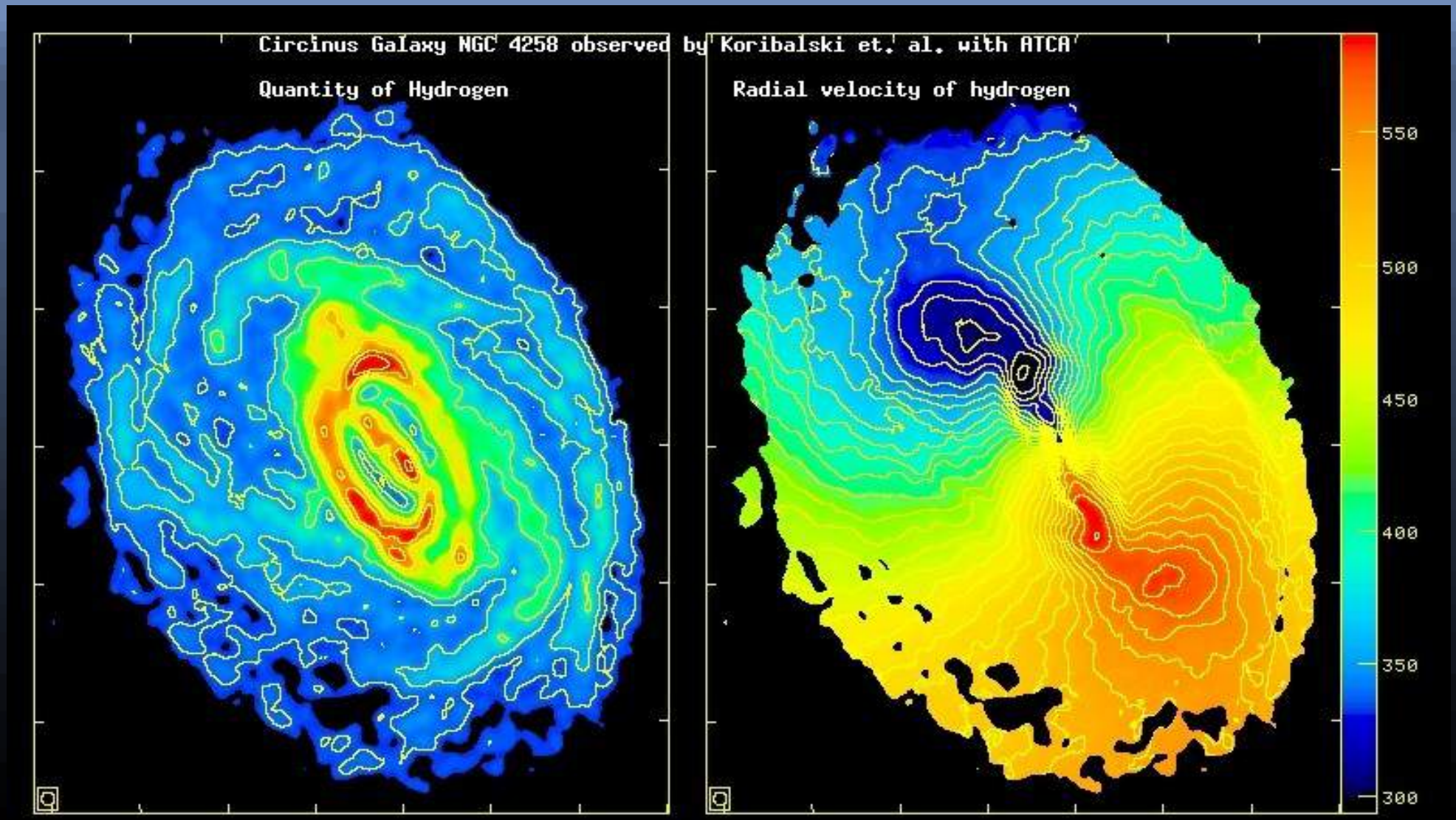
The signature of cold, neutral, diffuse, neutral, atomic hydrogen in interstellar and intergalactic space H I



$$\frac{\mu_{electron}\ \mu_{proton}}{(\text{Bohr radius})^3}$$

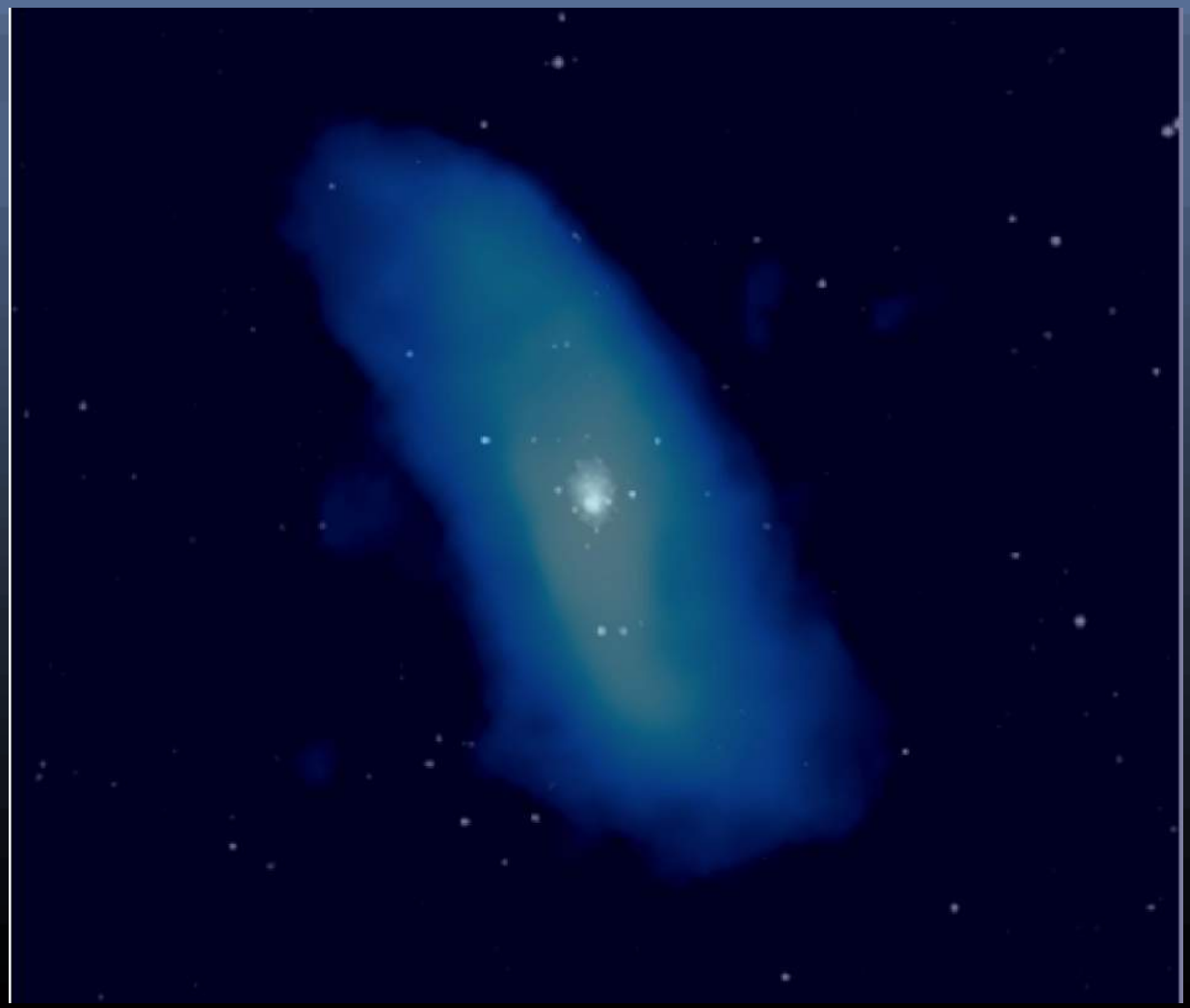


Hydrogen in NGC 4258 -e,n,p are a small minority in galaxies!

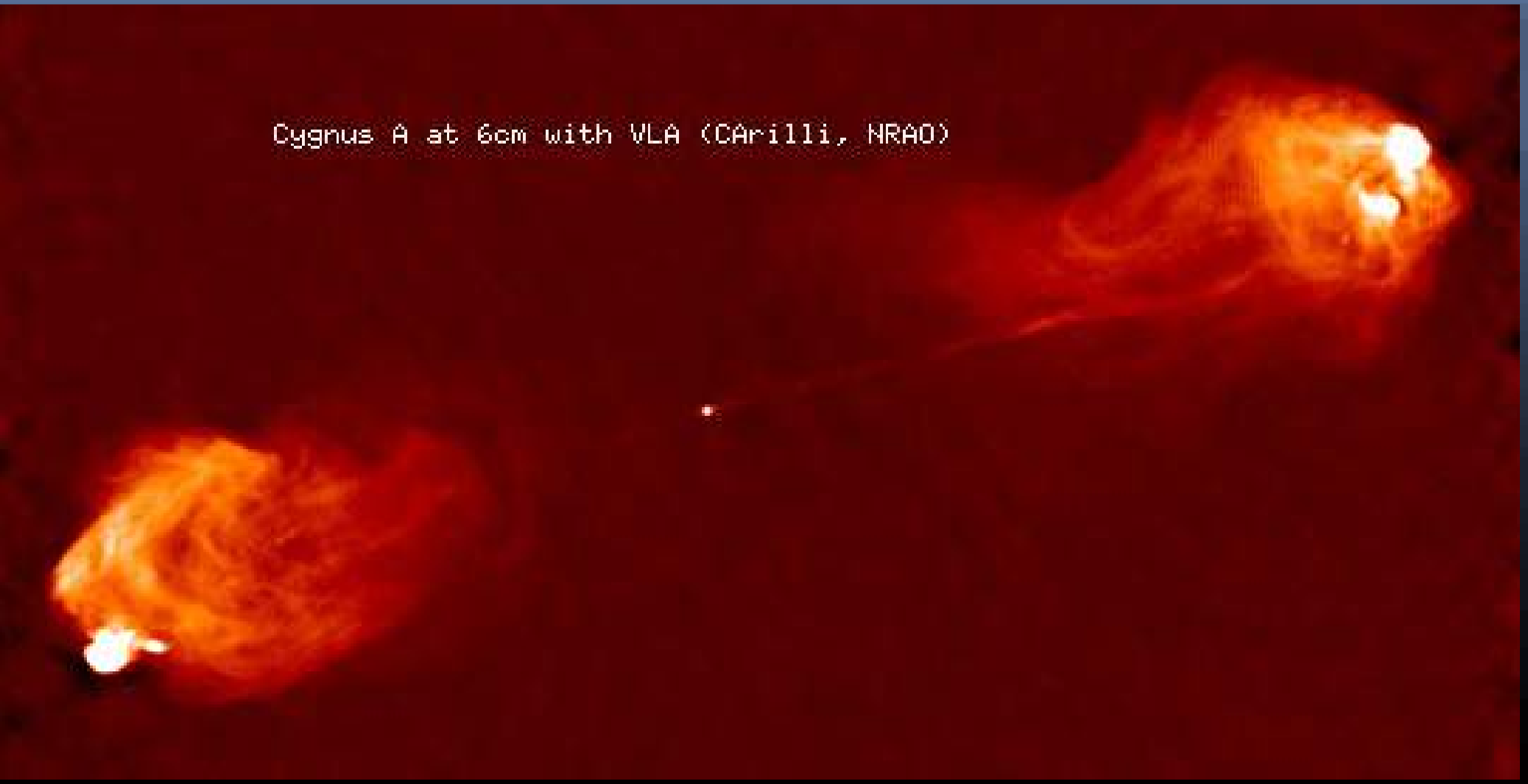


NGC 3741: A giant in dwarf's clothing: Part of a major survey FIGGS

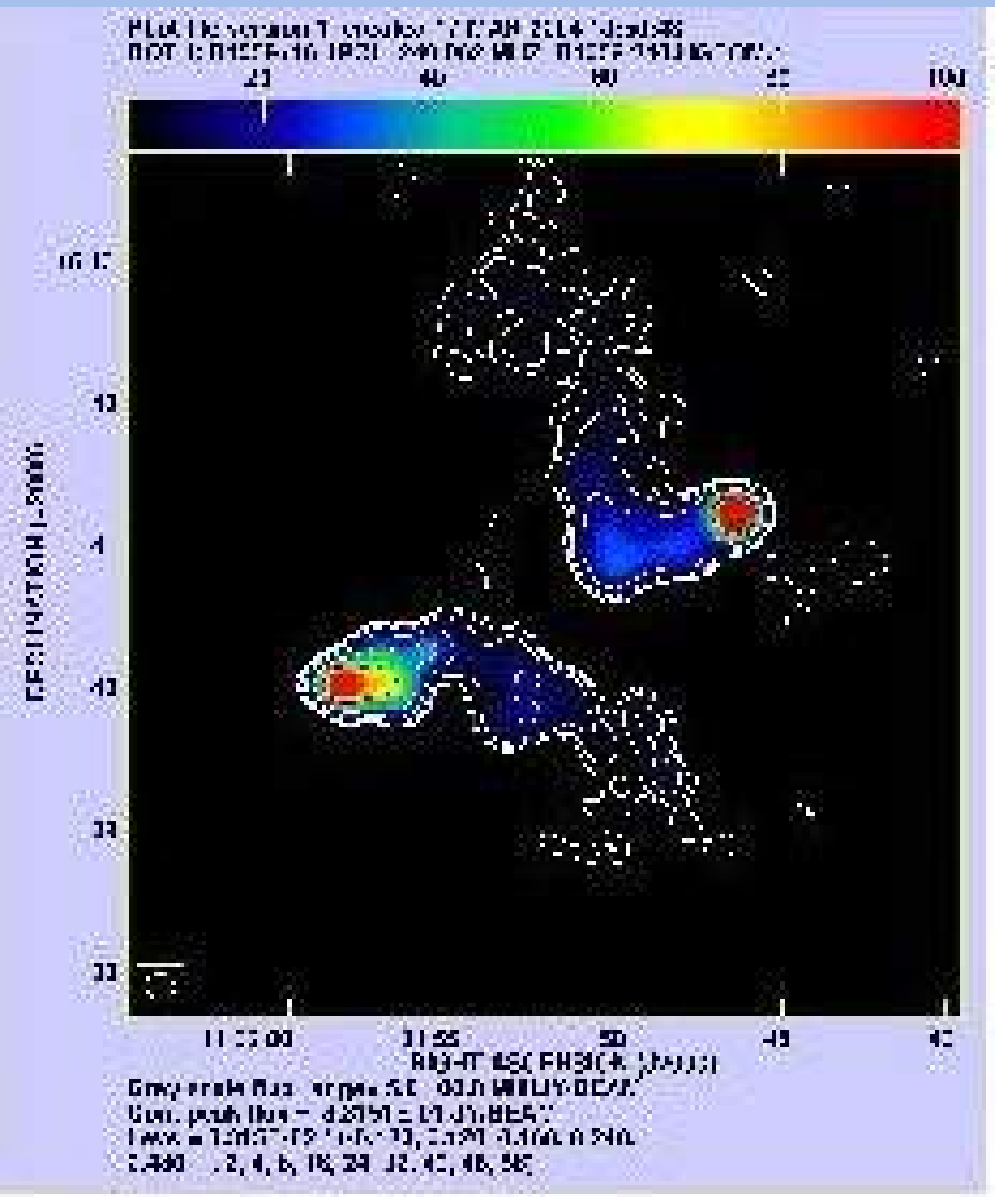
Ayesha Begum-(Sinha) and Jayaram Chengalur, 2005

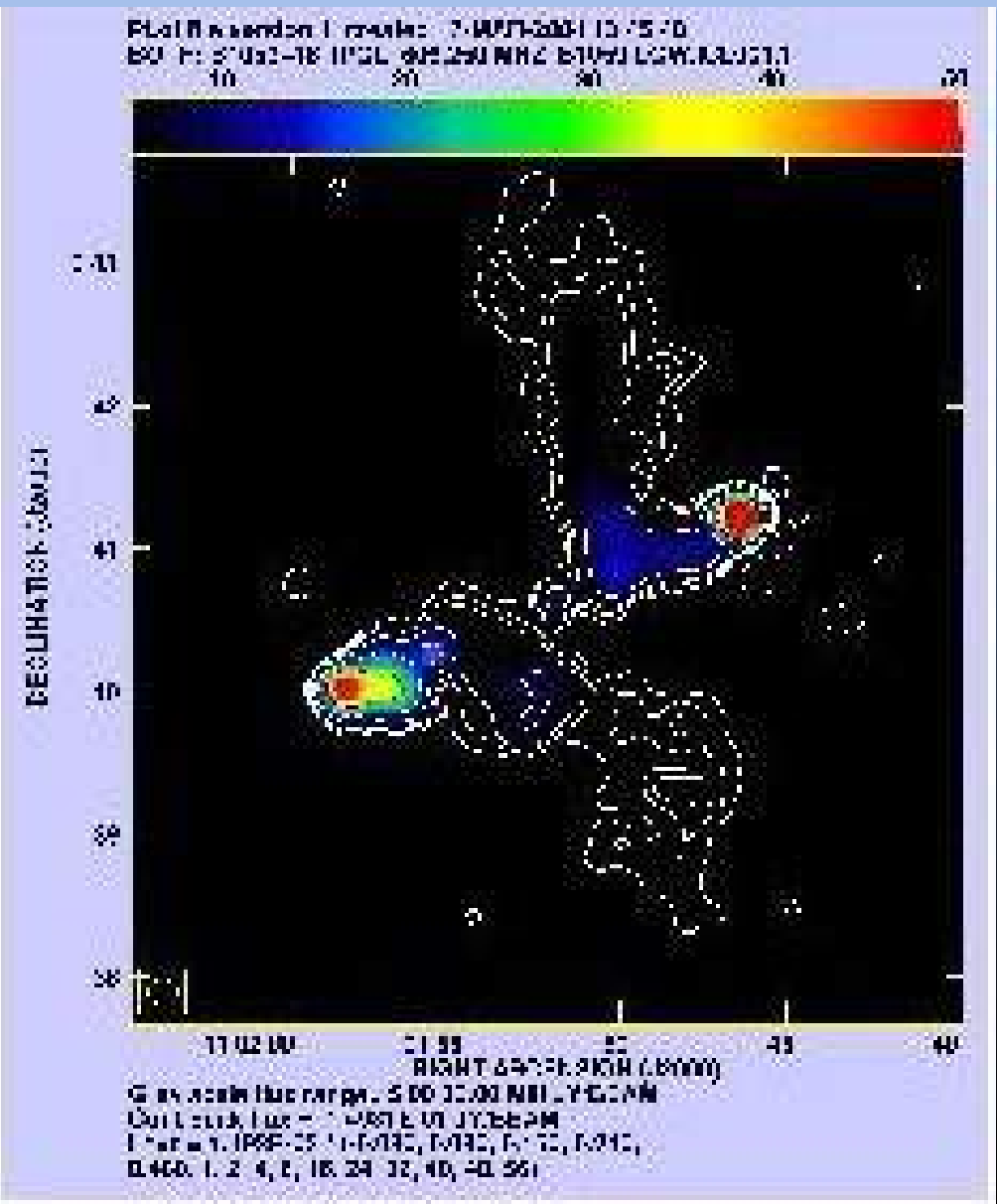


Black holes at the centres of 'active' galaxies: Cygnus A

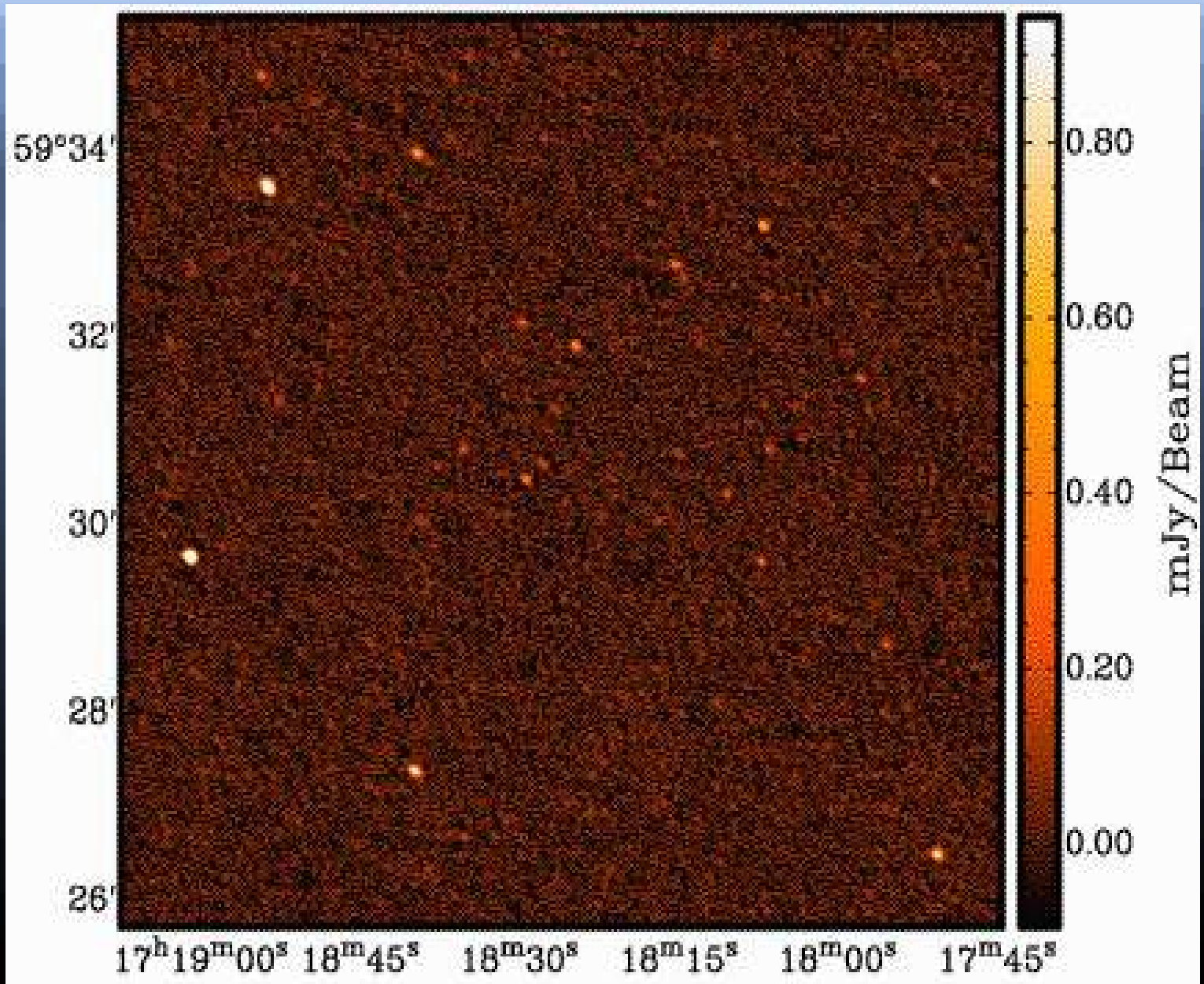


The X-files (Lal and Rao, 2004)



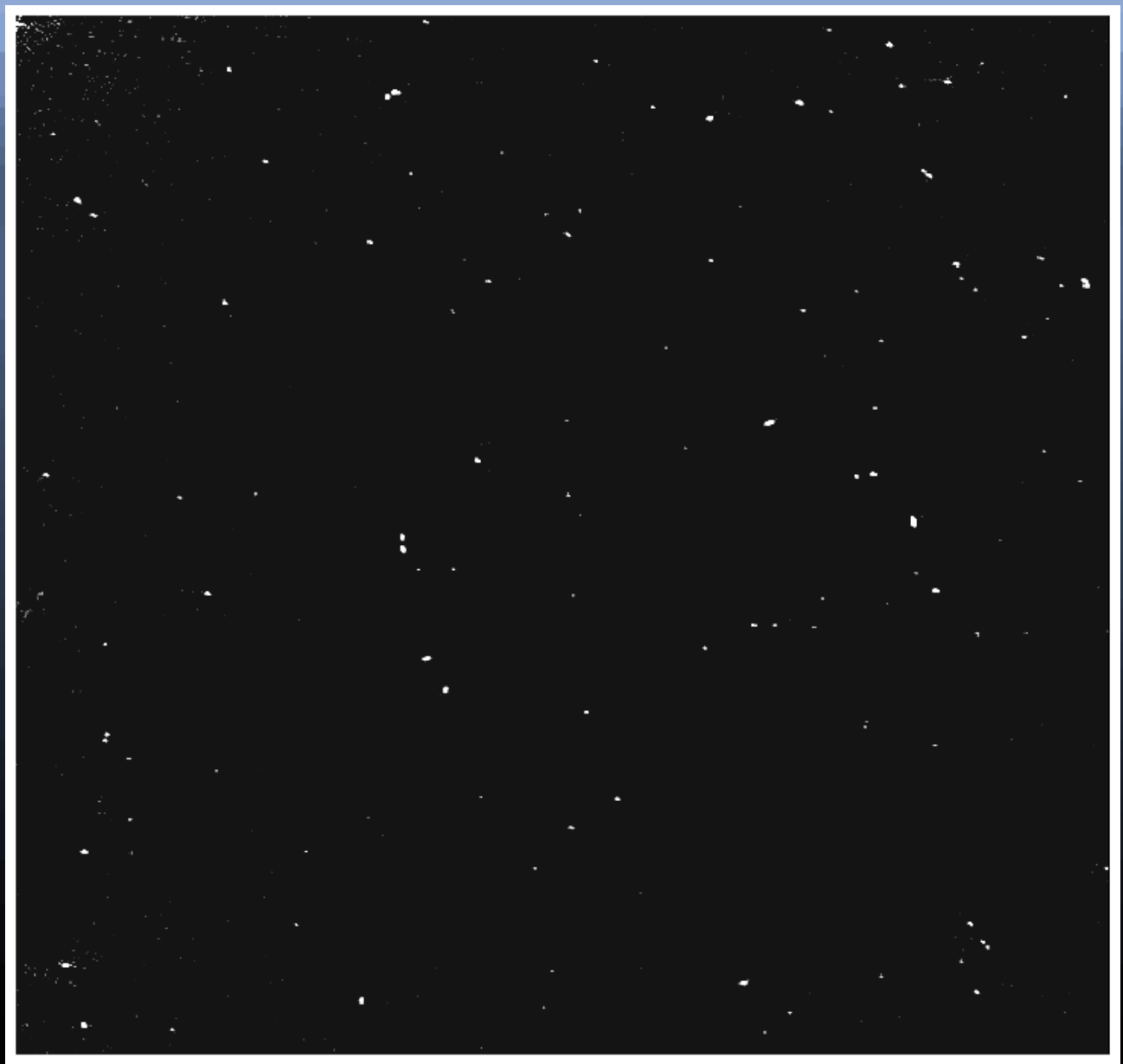


Deep view at 610 Mhz (Green and Garn)



TGSS -all sky at 150 MHz-

Sirothia, Ishwar-Chandra, Kantharia, Gopal-Krishna



Current new directions in radio telescopes

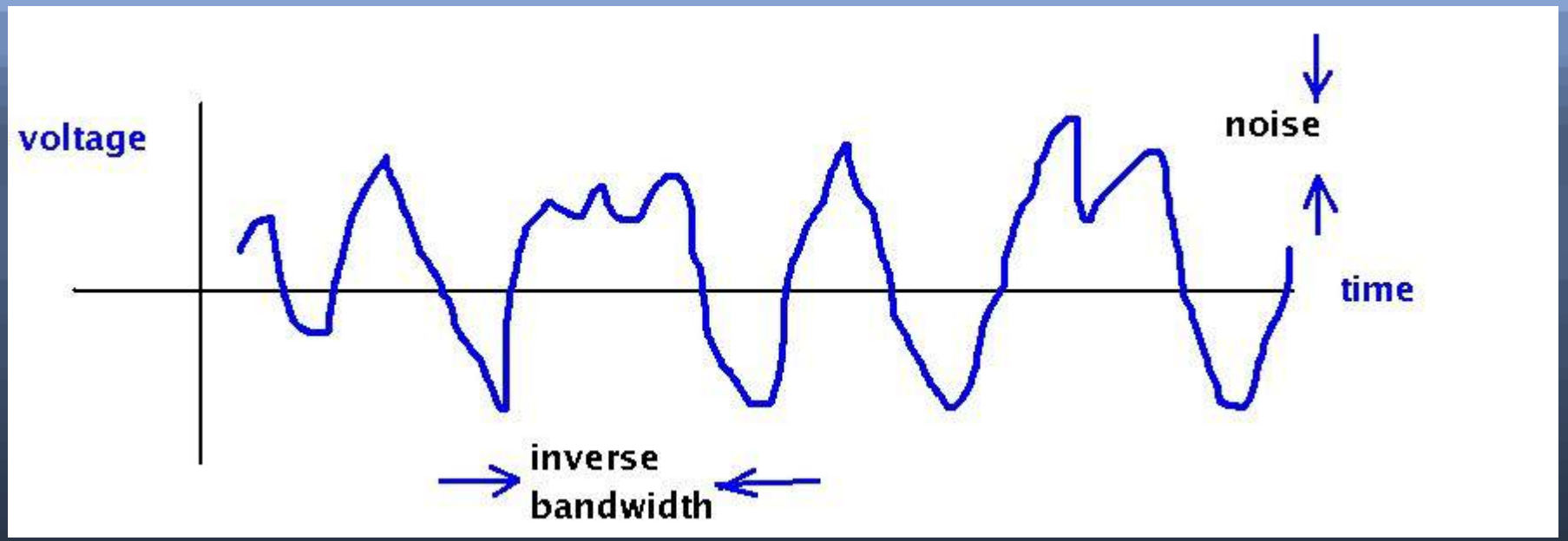
LOFAR in Netherlands: opening up 5 to 1 m

- GMRT upgrade to higher bandwidth and coverage of frequencies, in 0.2-2 (even 4) m
- ASKAP, KAT(South Africa) (0.5m-0.1m), large N small D
- e-VLA – very significant upgrade of a very successful cm wave telescope
- ALMA -millimetre wave radio astronomy – the study of molecules, hot ionised gas, and dust at far higher sensitivity and resolution than currently. Exploration of star and planet formation

The Square Kilometre Array -LHC of Radio astronomy

- International, 2 billion plus cost, 2015-2020
- two orders of magnitude hike in sensitivity
- Quiet southern sites,North Cape and Western Australia
- Significant low frequency component, to look at hydrogen atoms in the pregalactic and prestellar era
- Ultra high technology at ultra low cost - how?
- Challenges: mechanical, EM, fibre, digital hardware, software, data storage/retrival, use

The mathematical theory of communication



The signal to noise ratio is like the size of the alphabet and the Bt product is like the number of letters in the message

Shannon's way: increase bandwidth

- No uncertainty, no choice, no information
- the bit is the natural unit of information transmission, i.e log of no. of possible messages to the base 2
- there are (26)^4 entries in a dictionary of four letter words, all the way from AAAA to ZZZZ
- The capacity formula looks like (Bandwidth)*logarithm (1+Signal to noise ratio)
- Bad news for radio astronomy – e.g CDMA