

# Jodrell Bank, the Lovell Telescope, e- MERLIN and the SKA

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Museum of the History of Science

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THE UNIVERSE  
YOURS TO DISCOVER



INTERNATIONAL YEAR OF  
ASTRONOMY  
2009

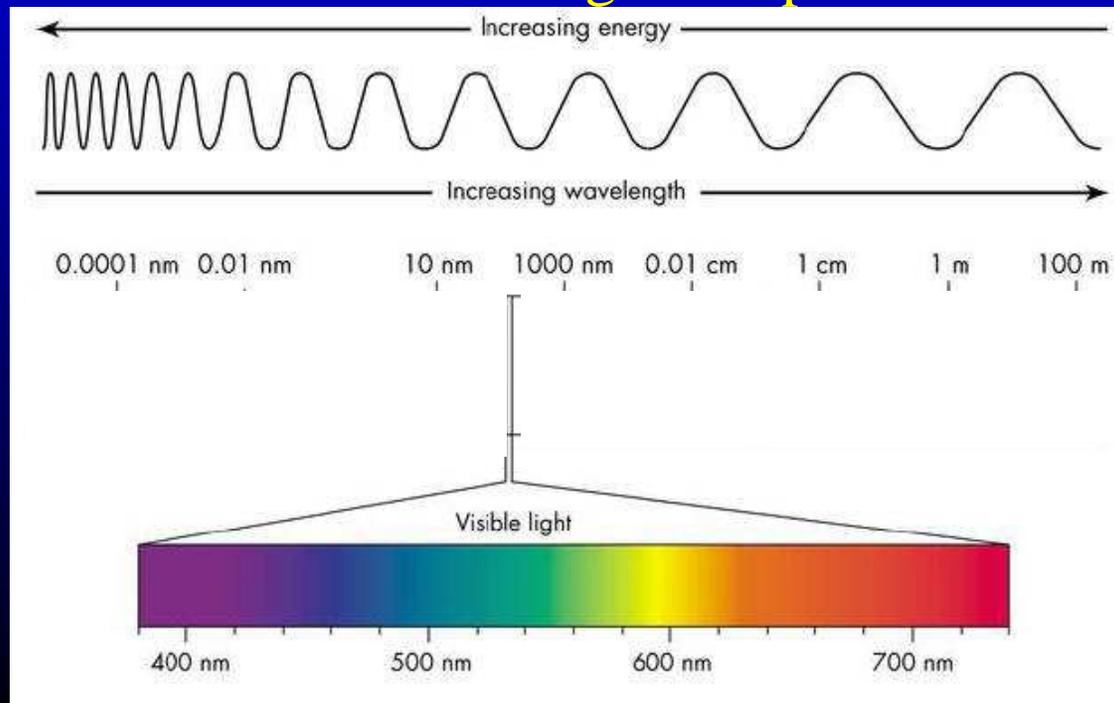
# Why explore this subject?

*‘Too many people and too many scientists think that a big machine of modern science is built because of a straightforward decision by a Council, a Committee or a Government department. It is not like that at all. Very rarely are the critical details of the interplay revealed... the historical account of 20<sup>th</sup> Century science tends to become a smooth veneer, a catalogue of instruments and dates. There is no inkling of the cauldron that has boiled beneath the surface.’*

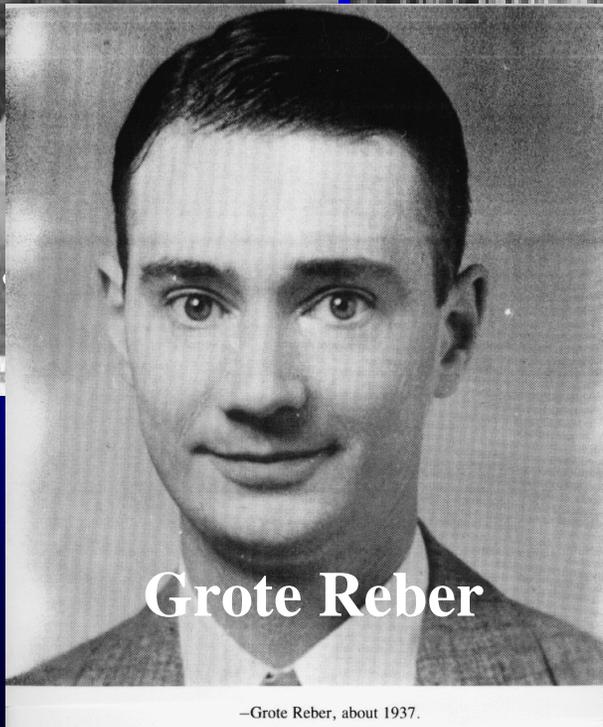
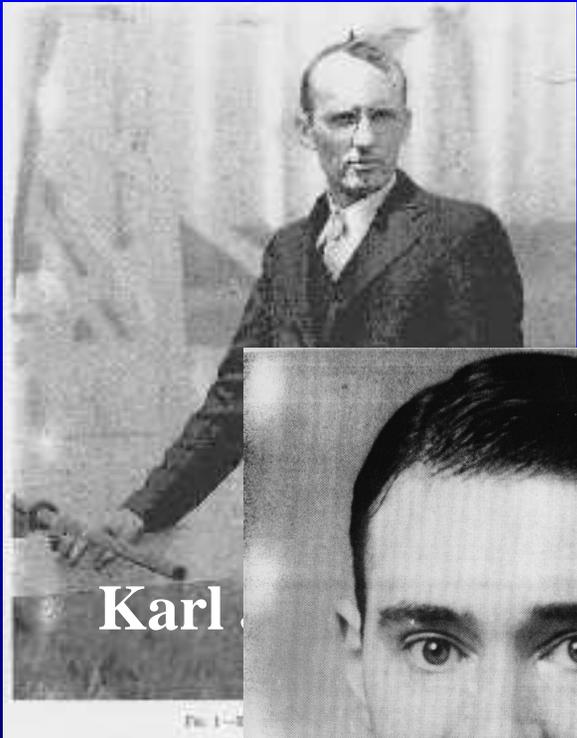
*A.C.B.Lovell, 1985*

# IYA2009

- The 400<sup>th</sup> anniversary of Galileo's first use of an astronomical telescope is the inspiration for IYA2009
- [Let us ignore Thomas Harriot of Sussex, who may have beaten Galileo to it.]
- For > 300 years our view of the Universe was limited to a tiny fraction of the electromagnetic spectrum:

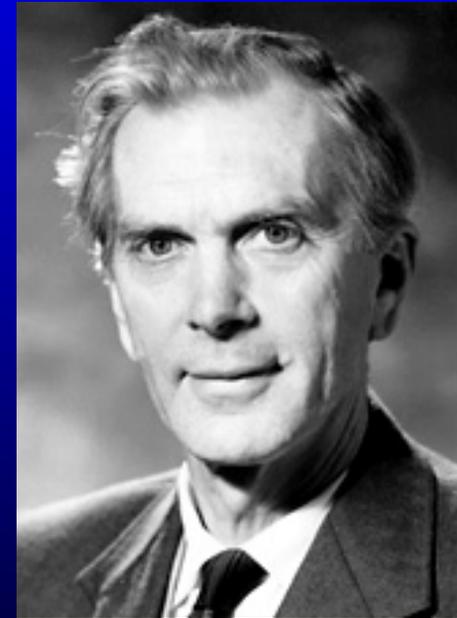


# 1930s: A new window on the Universe



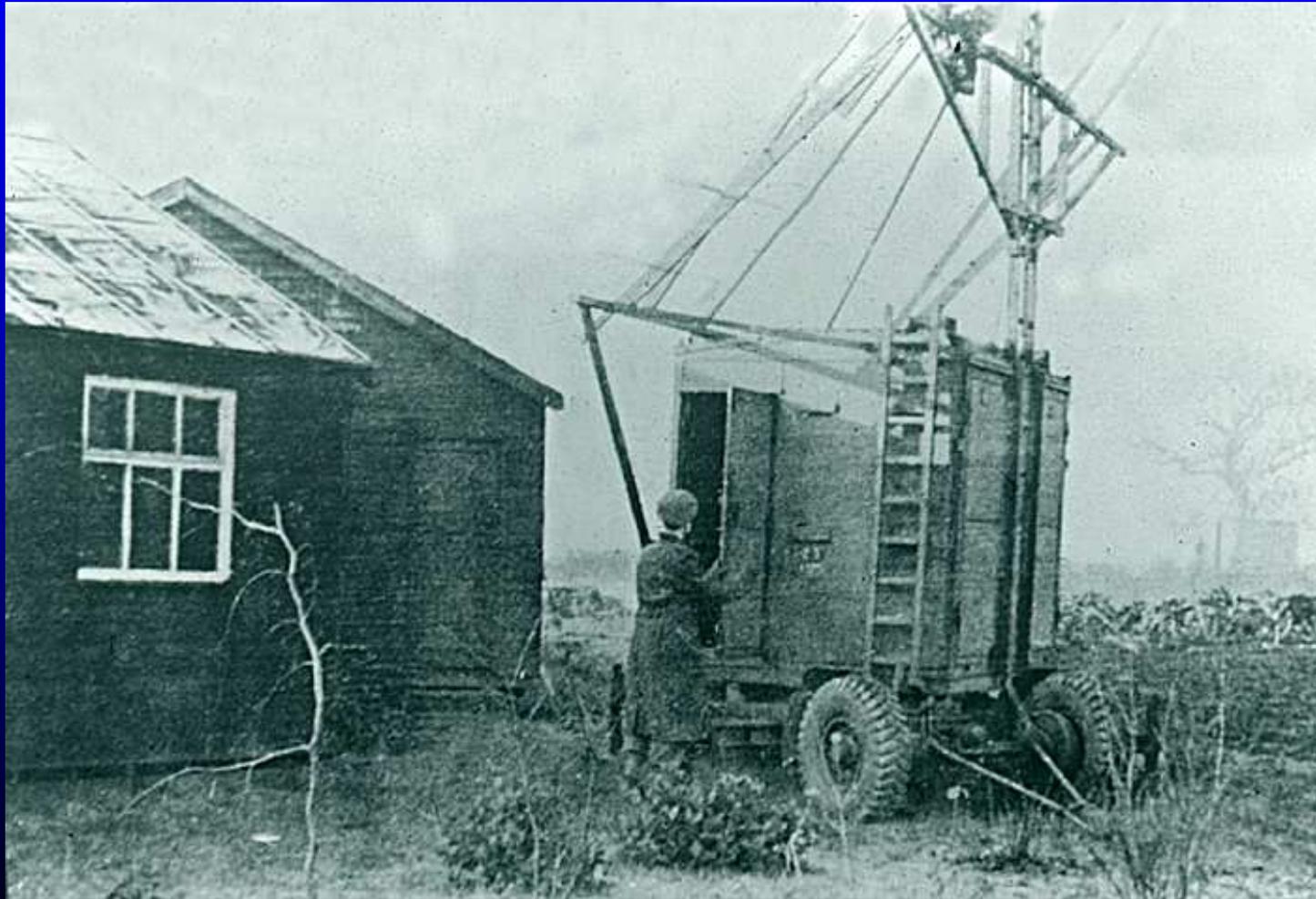
# 1945: peace dividend

- Many of radio astronomy's pioneers worked on radar systems during WWII – in all countries
- In 1945 they returned to their universities...

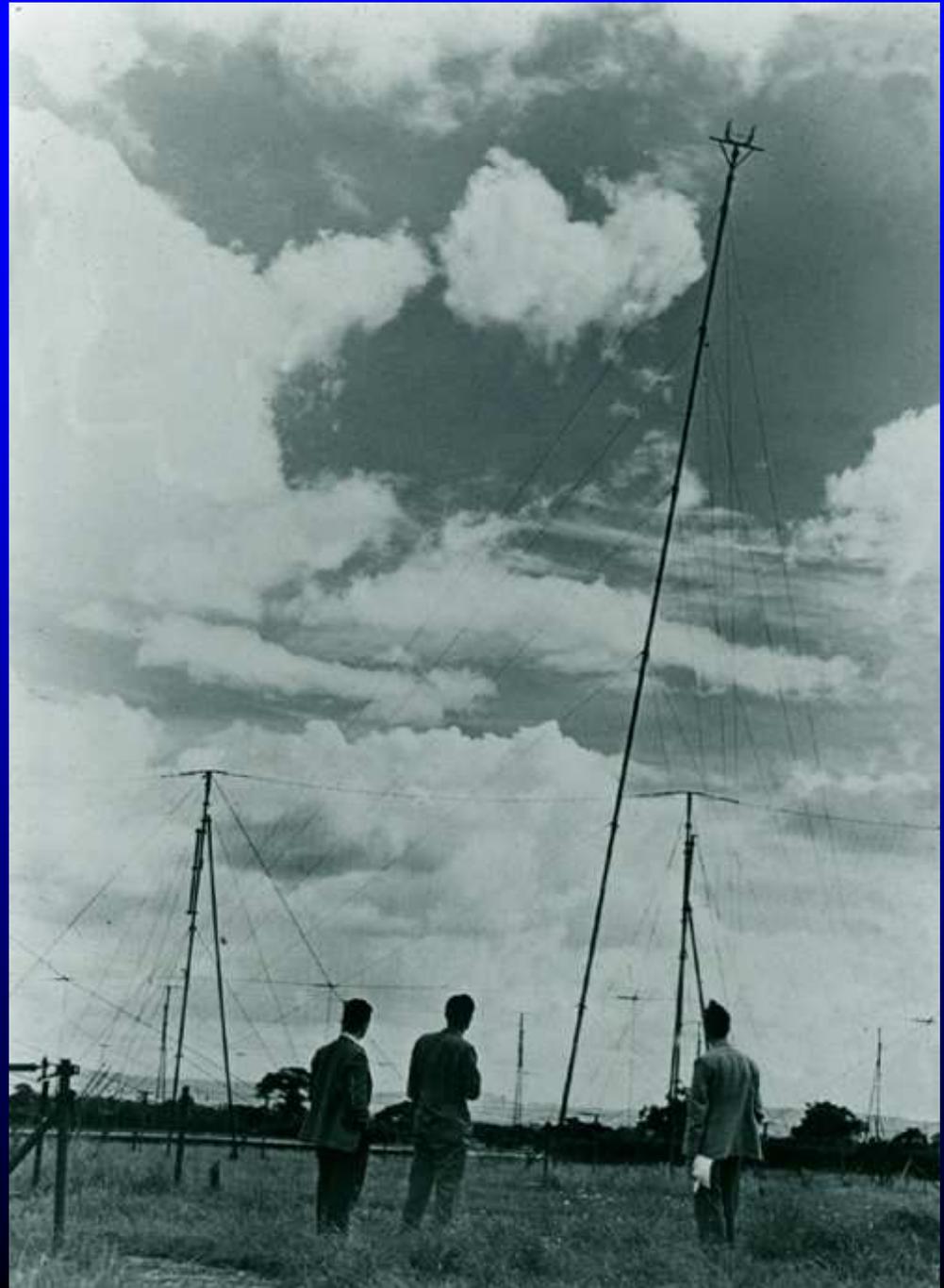


# The First Day at Jodrell Bank

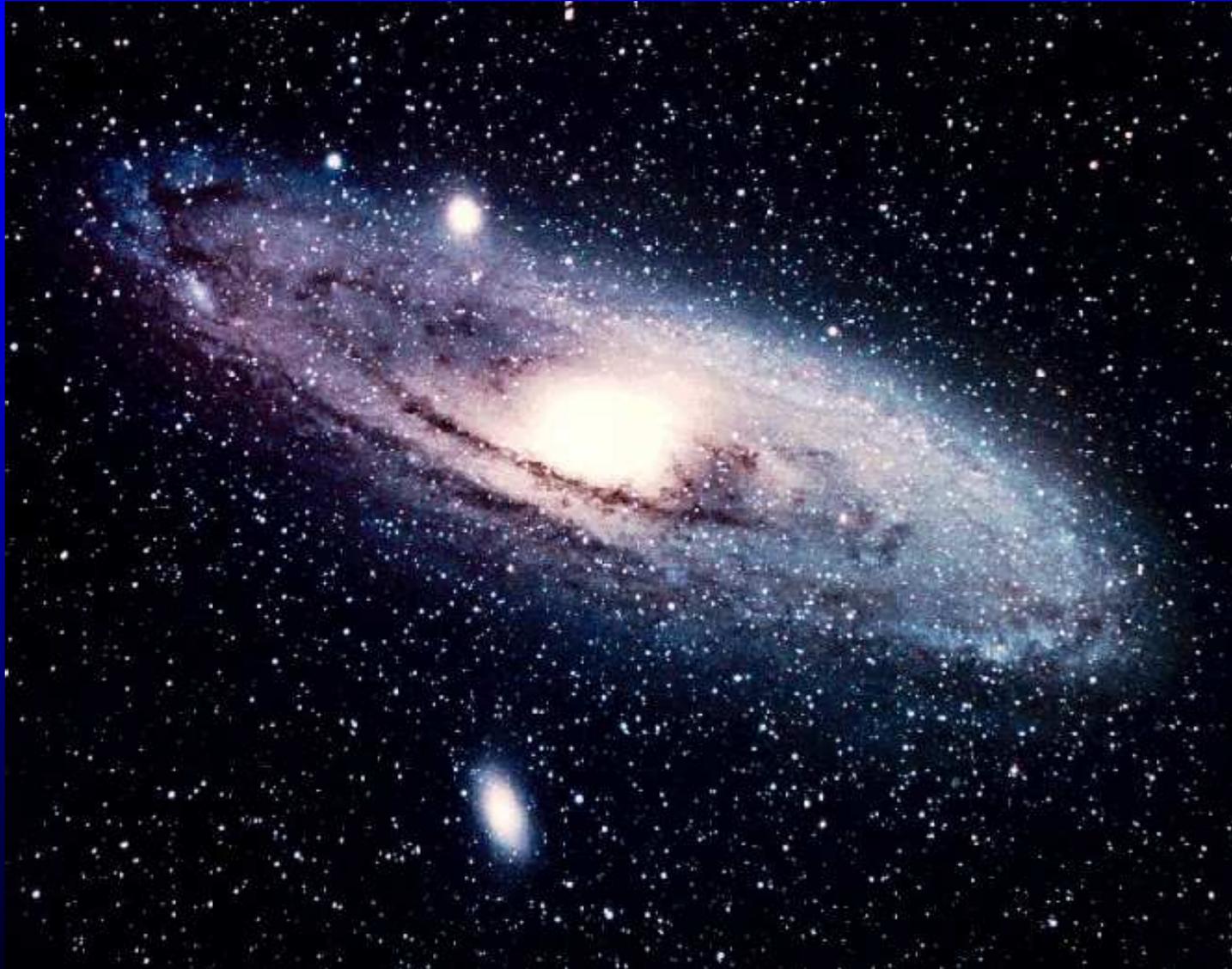
December 15<sup>th</sup> 1945



218 ft  
Telescope  
(1947)

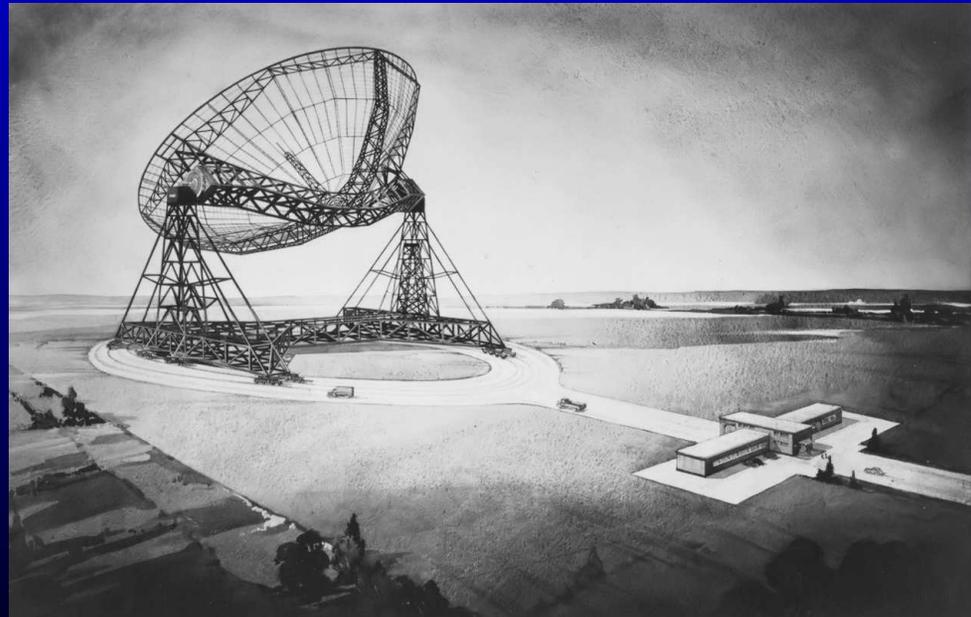


# The Andromeda Galaxy



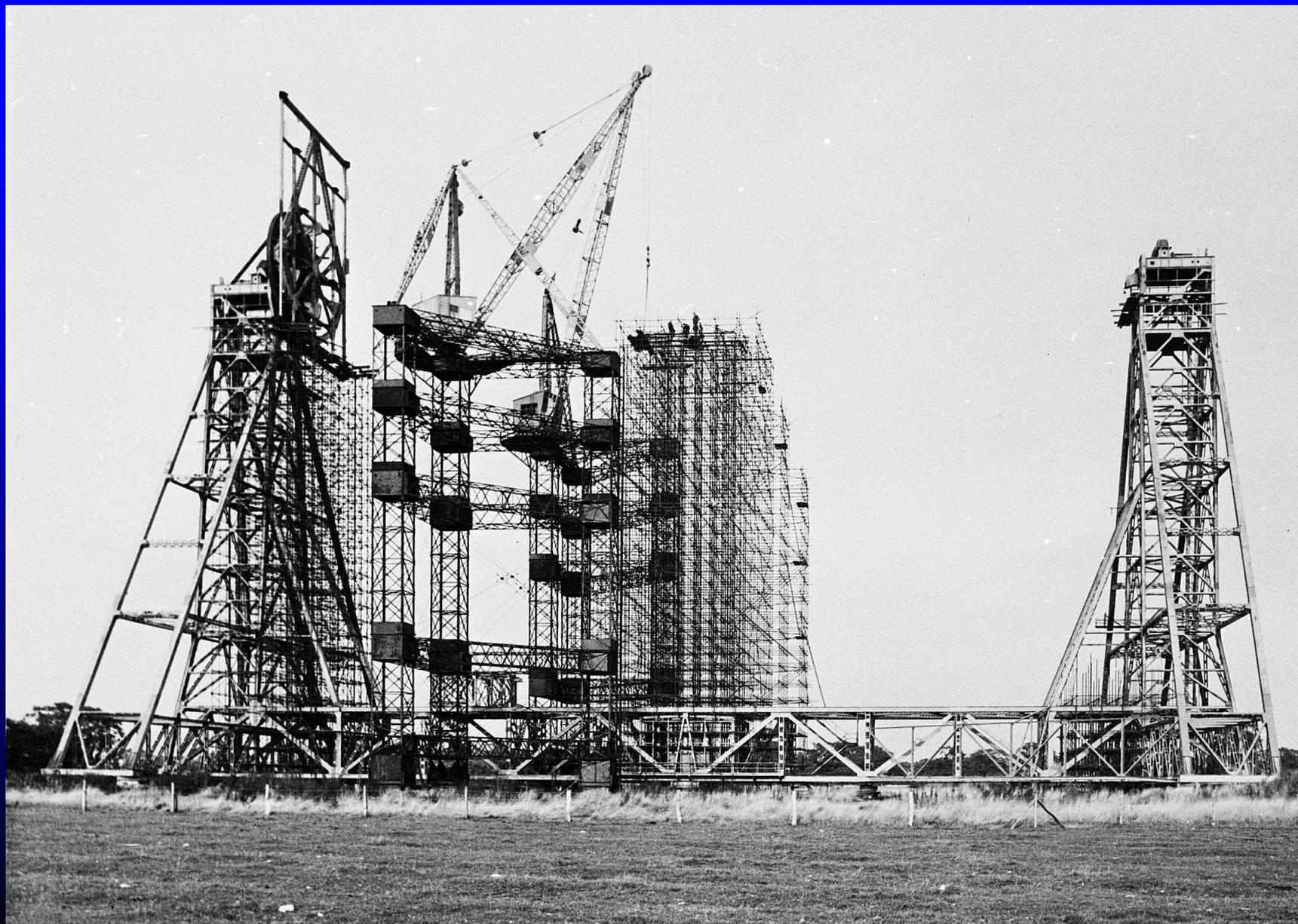
# The Genesis of an Icon

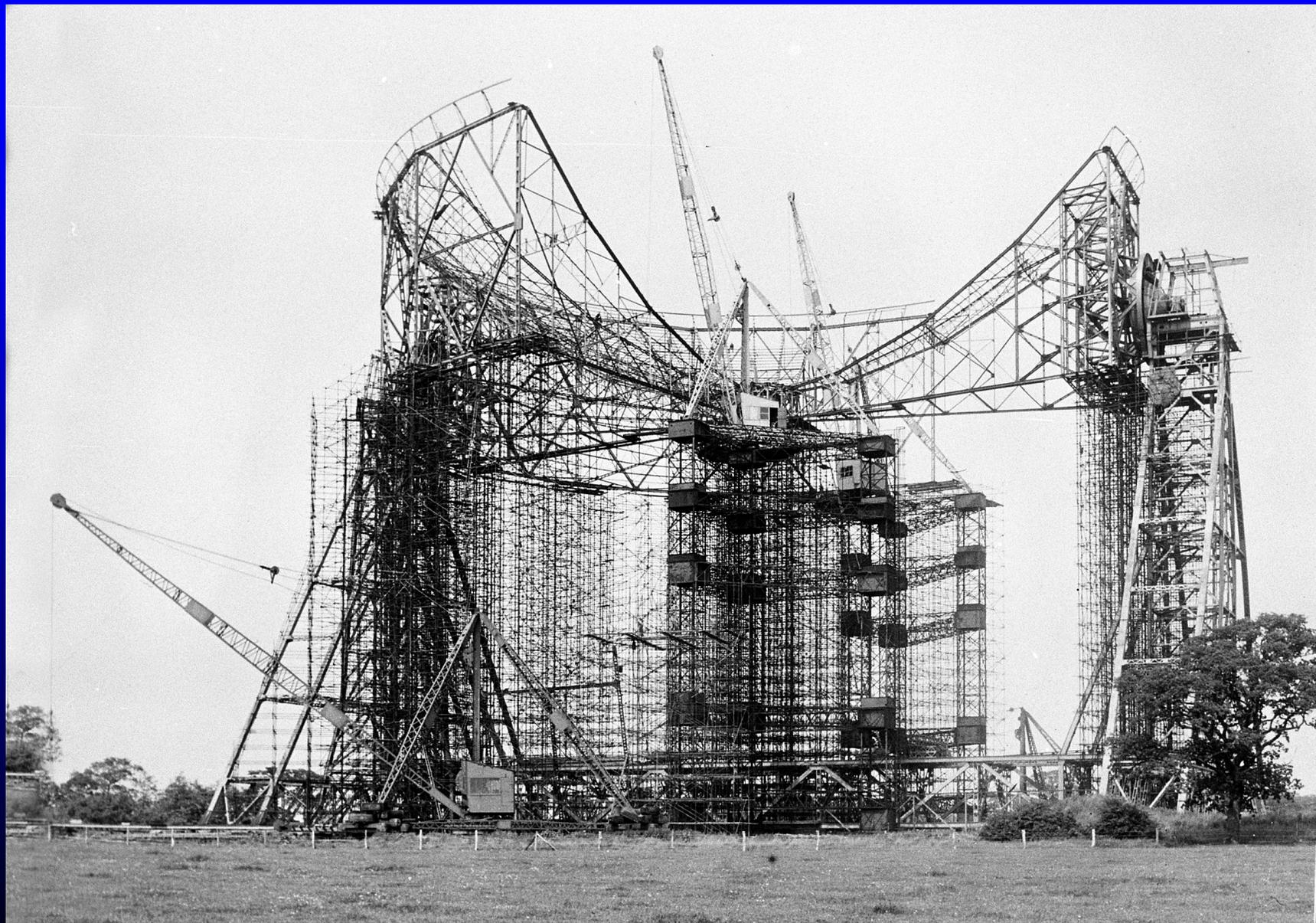
- Lovell and his team recognised the scientific potential of radio astronomy
- In 1951 wrote a proposal to fund a 250' steerable paraboloid, with following science goals:
  - Determine galactic structure
  - Solar physics
  - Radar echoes from planets
  - Meteors
  - Aurora

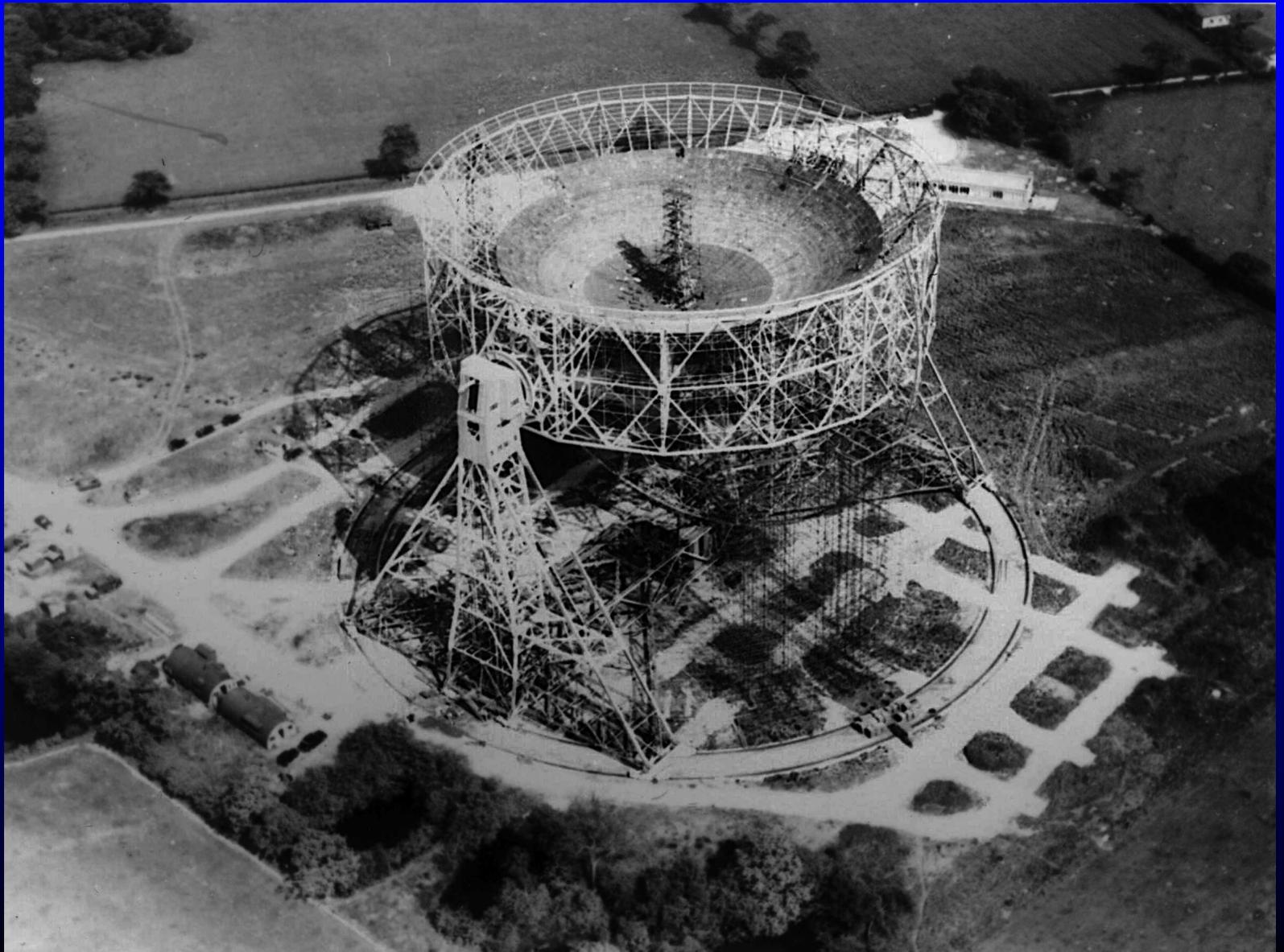


# National context in 1950s

- Britain bankrupt after WWII; heavily dependent on US Marshall Plan [remember, the loans negotiated at that time were only paid off in 2006!]
- Rationing still in place, meat was rationed until 1954
- National Service until 1963
- Britain engaged in series of costly small wars as tried to withdraw from Empire; Suez Crisis in 1956
- Cold War in full swing, huge scientific effort on developing H-bomb
- *‘as never subsequently, science and scientists were held in the highest regard. We had been crucial to the winning of the war and there was a facile optimism that we could work similar wonders in peace.’*











# Financial problems

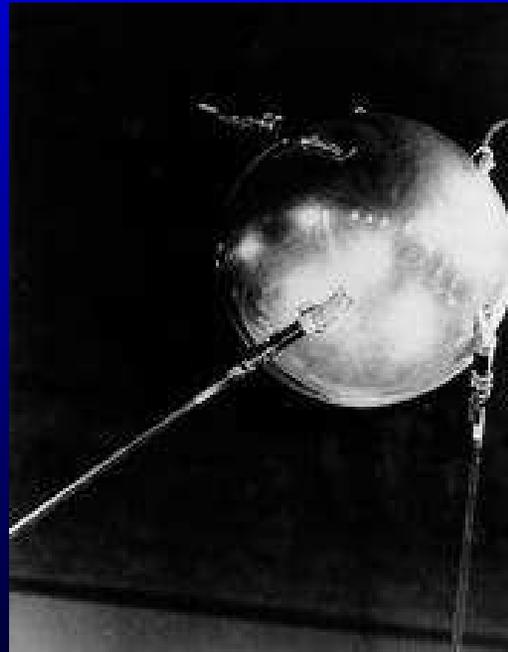
- The original grant for telescope construction was £335k (DSIR & Nuffield Foundation) [£6.9M in 2008]
- However, several re-designs:
  - Discovery of HI → solid surface
  - Air Ministry requests (secret until recently)
  - Never built such a structure before
- Final cost ~£700k [£12.1M in 2008], significantly influenced by cost of steel
- Government & University unable to cover costs. Husband not paid, United Steel not paid. Personal law suit against Lovell → threatened with jail.
- Lord Nuffield paid off balance post Sputnik.
- Point to note: it took 6 years from proposal to first light for a huge science and civil engineering project

# 1957 – The MK 1



# Sputnik 1

- On 12<sup>th</sup> Oct the 3<sup>rd</sup> stage rocket that put Sputnik into orbit (and which was itself in orbit) was conclusively detected.



**1971: Upgraded, became MkIA**

**1992: Renamed Lovell Telescope**

**2002: Resurfaced, new control system**



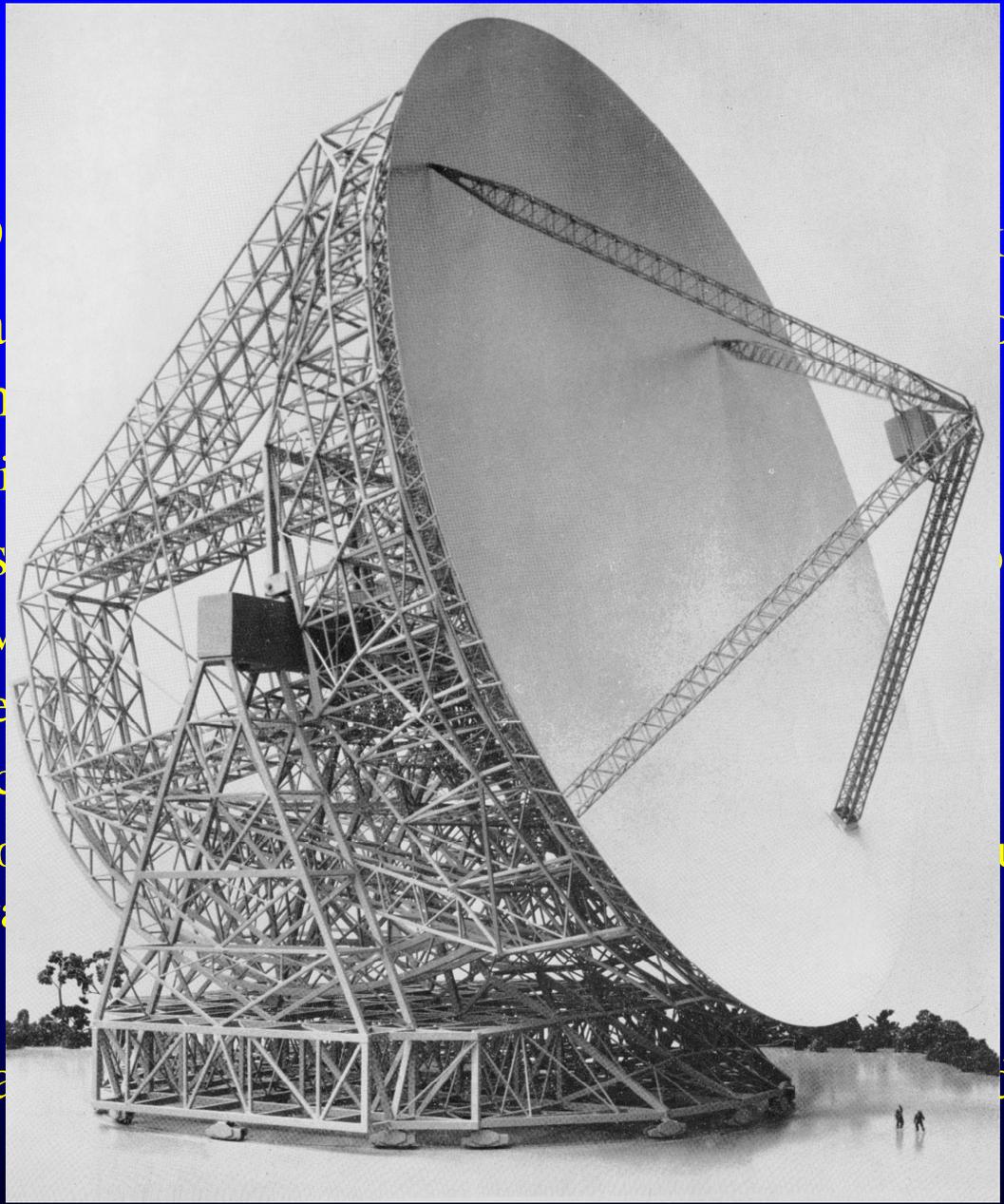
# An obsession with big telescopes

- Lovell was not satisfied with a 250' diameter telescope, he wanted ever larger dishes.
- In 1959/60 he was pursuing design funding for an elliptical dish 1500' x 500'
  - Project (MkIV) died but did lead to construction of MkII and MkIII telescopes
- In 1960 DSIR asked Lovell and Ryle to prepare a strategic plan radio astronomy in the UK →
  - Aperture synthesis at Cambridge
  - MkV and radio-linked interferometry in Manchester

[exercise underway again.]



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# A study in frustration...

- Choosing a site – decided not to build at Jodrell Bank
- Sir Graham Smith led the site surveying:
  - Explored the English/Welsh border area
  - Built a van and interference testing equipment, but had to be very careful locals did not uncover University's interest because *'extraordinary financial and other problems may be placed in our way by the local community'*.
  - 1965 chose Meifod near Welshpool
  - In Sept 1973 obtained planning permission despite strong local opposition, including a public inquiry

# A study in frustration... (cont.)

- Politics:
  - Harold Wilson called an election for June 1970...and lost!
  - Heath became PM with Margaret Thatcher as Sec State for Education and Science
  - New Chancellor of Exchequer worried that govt expenditure was 50% of GDP, decided to cut research councils budgets.
  - Telescope was descope'd, to 375ft diameter
  - Government delays led to continual increases in price : £17M [£127M]
  - ‘*The bogy of European collaboration*’:
    - Germans built 100m Effelsberg telescope, using homology – much cheaper and lighter
    - British government looking for European collaboration – saw astronomy as one aspect of this
    - UK astronomers offered 40% time on Effelsberg – without the knowledge of Director of Max Planck Institute fur Radioastronomie!
  - June 1974, MkV project cancelled.

A second strand

Interferometry

=

high-resolution.

Separating telescopes spatially is equivalent to synthesising an aperture of diameter equal to the distance between the telescopes.

# Radio Linked Interferometry

- Signals from a remote telescope were brought back to Jodrell Bank by a microwave radio link



# The quest for high resolution.



# Long baselines

- Cambridge, Dutch, Australian and US astronomers were constructing short-baseline interferometers,
- Jodrell Bank was using radio-links between telescopes ~127km apart – discovering fine-scale, compact structure in radio sources.
- Henry Palmer (leader of the interferometry group) persuaded Lovell to pursue an array and MTRLI was born from the ashes of the MkV.
- Idea was to purchase three 80ft dishes from USA – same as used in the VLA.

# The VLA



# Political, financial, logistical problems...but less of them

- Originally only 1 new telescope funded, partly through financial constraints but also because Cambridge colleagues had expressed some doubt that there were enough compact radio sources to be detected.
- December 1977, Hewish withdrew the Cambridge concern and full project was funded:
  - £5.6M in 1980 [£17M]
- 1980: MTRLI achieved first science – was renamed MERLIN in 1981.
- [Personal note: I became a PhD student at Jodrell Bank in October 1979, I was one of the first users of MERLIN.]

# MERLIN



Jodrell Bank



Tabley



Knockin



Cambridge

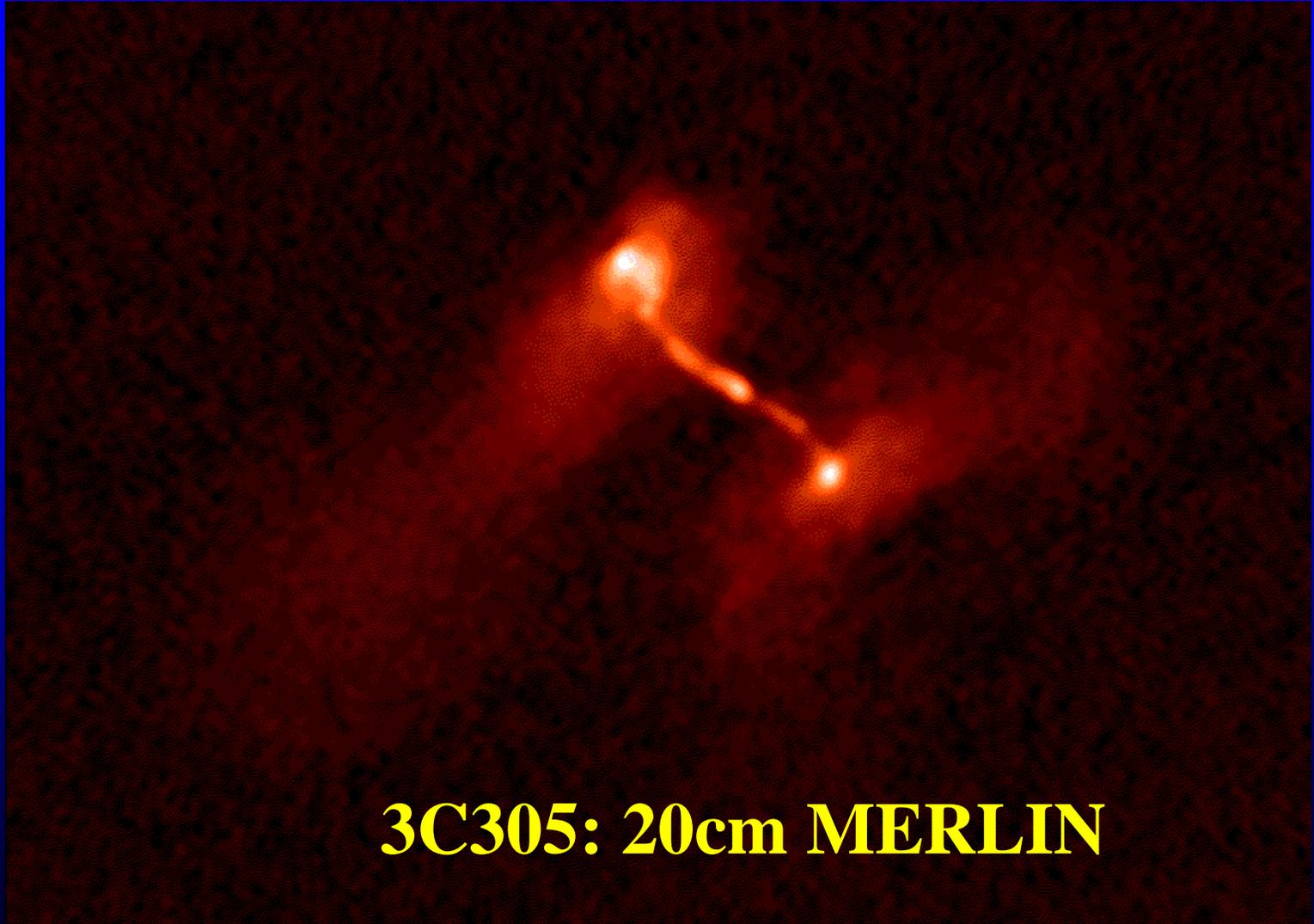


Darnhall

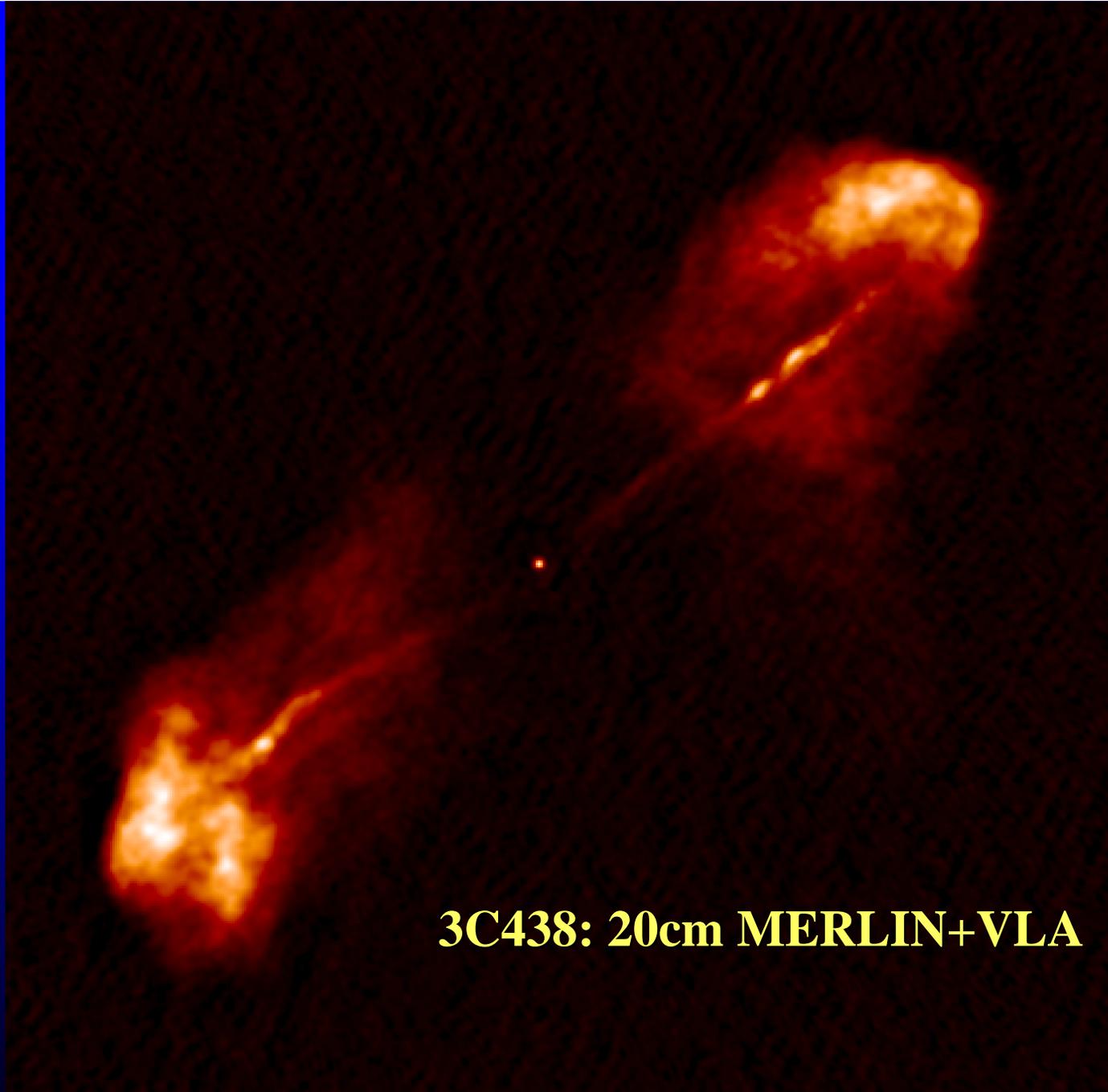


Defford

# Some MERLIN Science



**3C305: 20cm MERLIN**

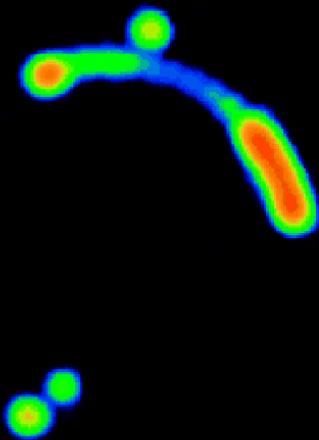


**3C438: 20cm MERLIN+VLA**

# Einstein Ring



**HST**

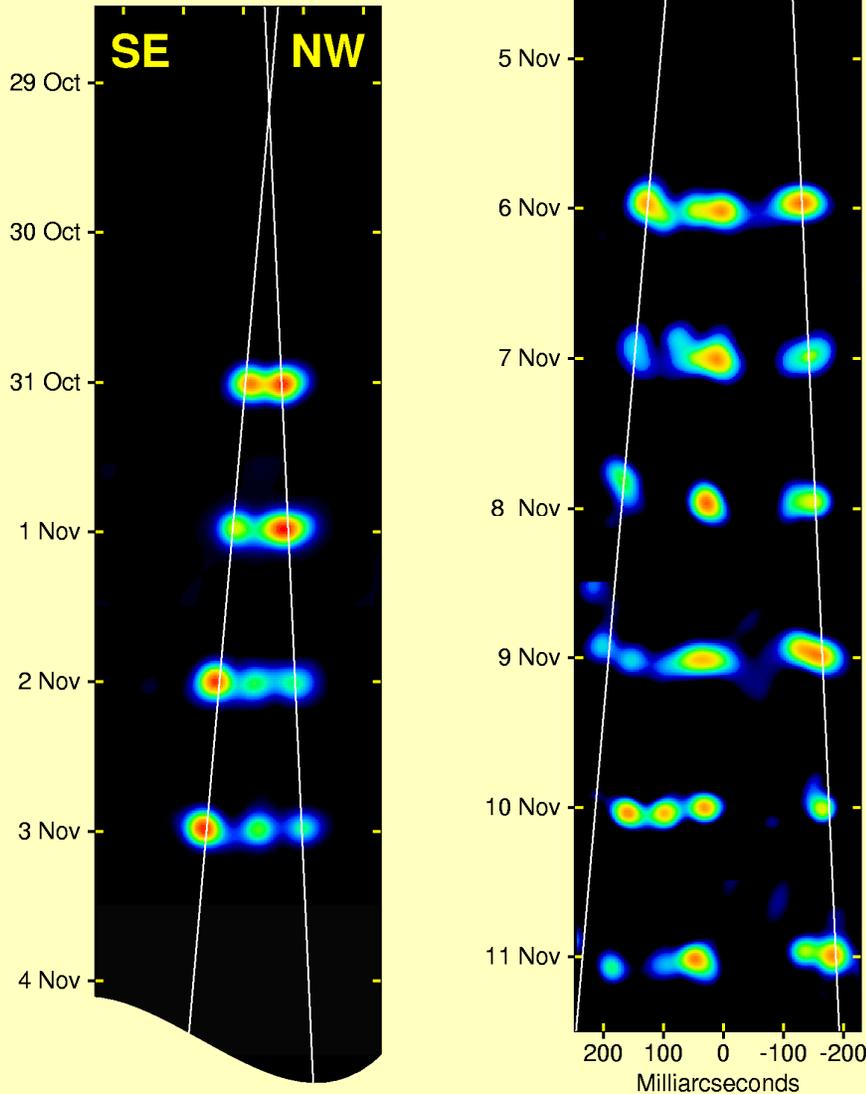


**MERLIN  
6cm**

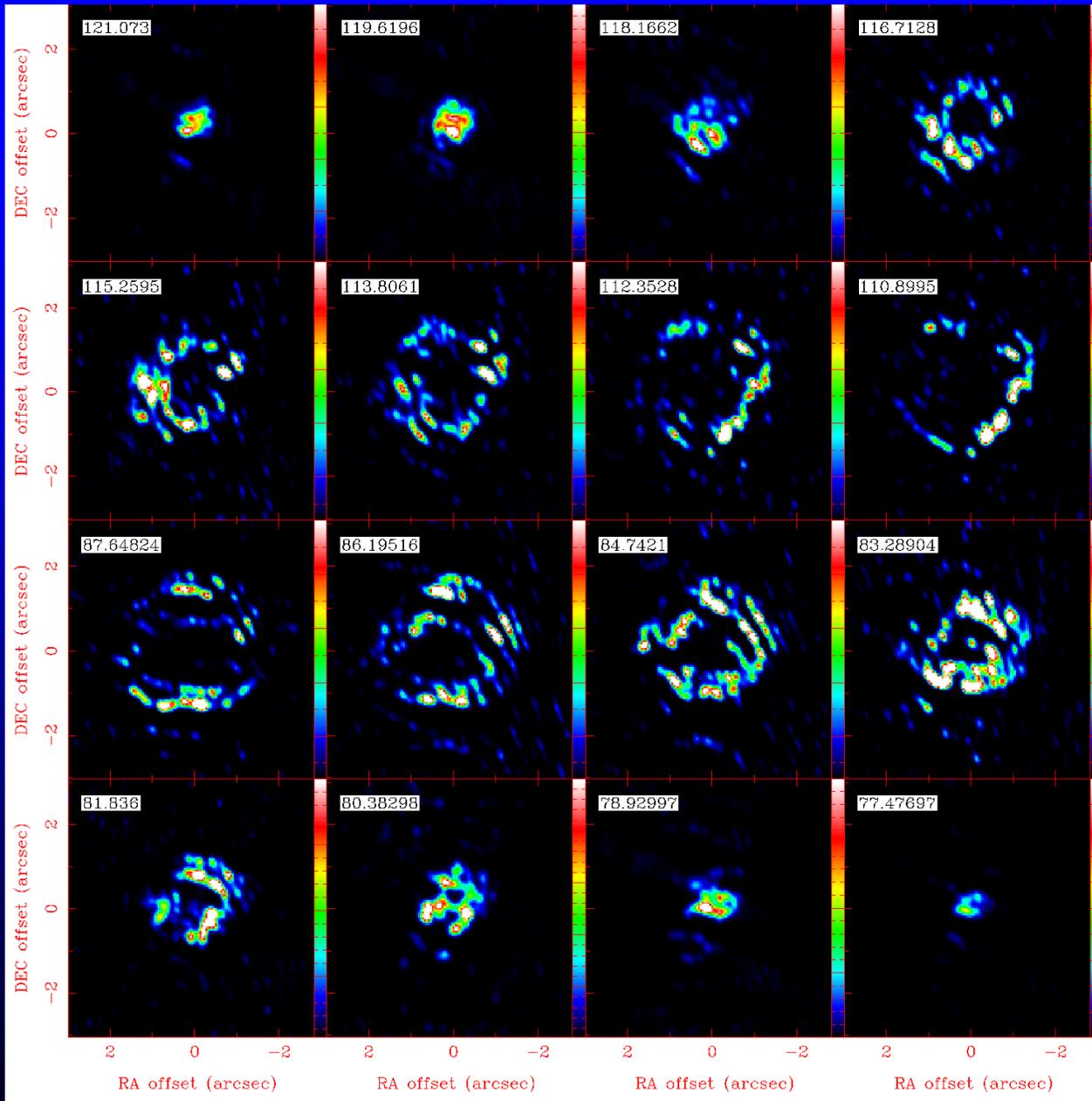
- Gravitational lens B1938+666
- IR image from HST shows a perfect Einstein ring, lensing galaxy at centre
- MERLIN does not detect radio quiet lensing galaxy.
- Radio ring incomplete because of slight mis-alignment of lensing system.

# MERLIN

GRS1915+105 4994 MHz

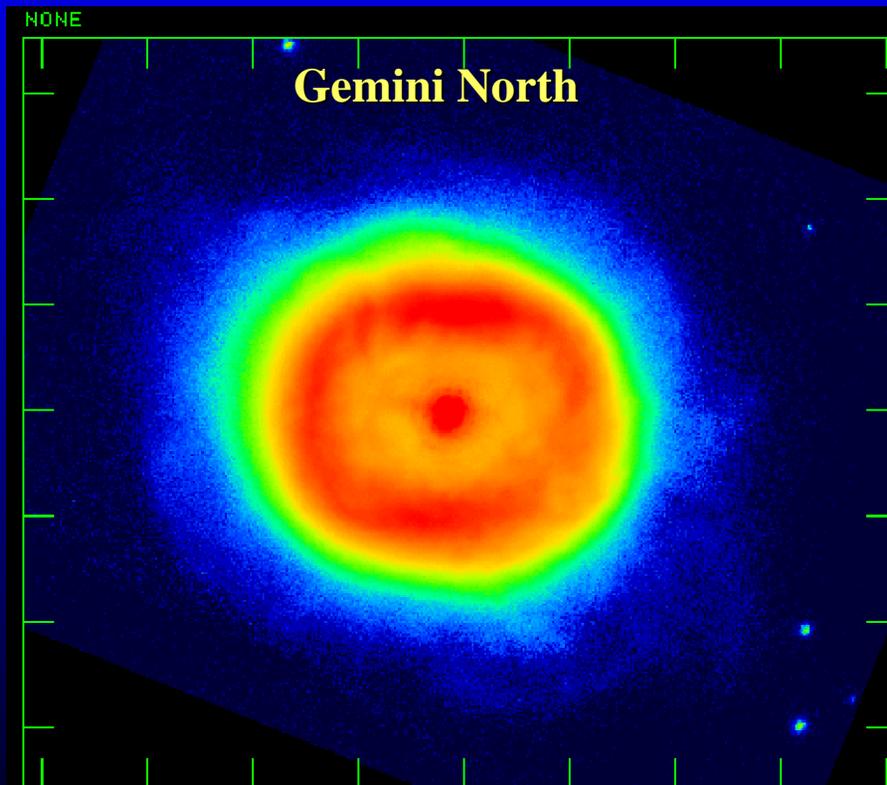


- GRS1915+105
- Microquasar in our galaxy, flared in Oct. 1997
- Daily MERLIN observations show expansion of twin relativistic jets at  $\sim 0.98c$

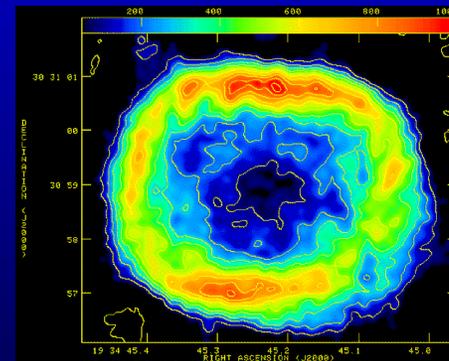


- MERLIN observations of OH masers around the OH/IR star OH30.1

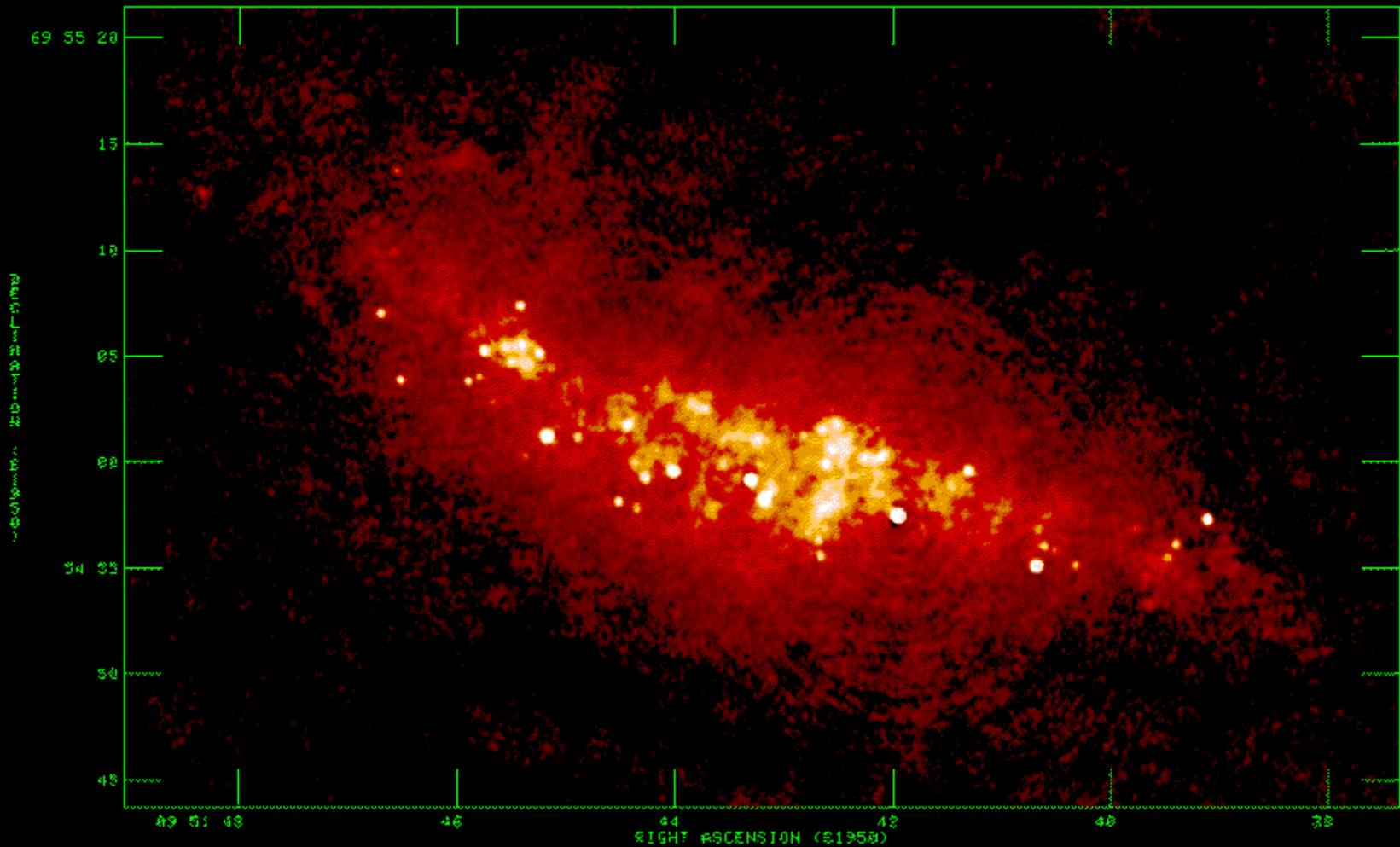
Gemini and MERLIN images of the planetary nebula BD+303639 on similar scales. The resolution of MERLIN (8 – 150 milliarcsec) matches well with that of GEMINI (77 milliarcsec in this case).



**MERLIN**



# M82 - MERLIN & VLA (20cm)



- MERLIN and VLA image of the 1.4 GHz emission from M82. Compact components are all supernova remnants

# e-MERLIN

- In January 1999 I took over as Director of MERLIN
- In June 1999 I initiated the e-MERLIN project via a presentation to PPARC's Ground-based Facilities Committee (GBFC), building on original ideas by Jim Cohen and others
- What is e-MERLIN?
  - Using modern, state-of-the art technology we are broadbanding MERLIN
  - 650 km fibre optic network, 210 Gbps – 3x internet traffic of UK
  - New receivers, electronics, software
  - With upgraded Lovell Telescope will be 30 times more powerful than MERLIN

# MERLIN

- Feb 1995: MERLIN
- Oct 1997: MERLIN
- Committee (GBF)
- Oct 1998: MERLIN
- Feb 2000: e-MERLIN
- Mar 2000: PPARC
- May 2000: IoP re
- July 2000: 'Jodre
- Aug 2000: NW S
- Sept 2000: Intern
- Nov 2000: submi
- Spring 2001: cap
- March 2001: piv
- Summer 2001: en
- June 2001: Wade
- Sept 2001: Techn
- Dec 5, 2001: e-M



ed Facilities

rejected



# What really happened?

- Cost evolution:
  - £16M gold-plated budget early 2000
  - £11M silver-plated budget, following international review
  - £8.6M final budget, following ‘get real’ discussions
- Political situation:
  - UK was joining ESO – cost £70M + £10M annually?
  - Gemini telescopes being constructed
  - SCUBA-2 approved, higher priority
- However, following PPARC-UMan ‘scuffle’ in Aug 2000, Ian Halliday (CEO PPARC) and Martin Harris (vice-Chancellor UMan) agreed to a deal splitting cost between UMAN, PPARC and NWDA
- Malcolm Longair & Richard Hills from Cambridge + colleagues from UMIST were brave and far-seeing, provided £250k each from their SRIF funds.
- Original timeline had e-MERLIN operational in 2008, will now be 2010
- In truth, we were cut too far and that has caused delays. £11M was probably the correct number.

# Problems are never far away...March 2008



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From [The Times](#)

March 6, 2008

## World-leading telescopes face being shut down to save £2.5m



**TIMES RECOMMENDS**

- ▶ Diplomat dealt with Thatcher's hair as Iran burnt
- ▶ Blue Peter sidelined by The Weakest Link
- ▶ Nursery 'is better than granny for toddlers'

**PARENT POWER**



Jodrell Bank has been responsible for some of the most important astronomical discoveries of the last 50 years

# The Square Kilometre Array

## Vital Statistics

1 km<sup>2</sup> collecting area

Continental Scale

Core: 5 x 5 km

Remote: >3000km

Sensor Network

10<sup>18</sup> Flop

10<sup>12</sup> bits/sec



# Dark Ages

- Emergence of the First Stars in the Universe
- Influence on evolution of the Universe

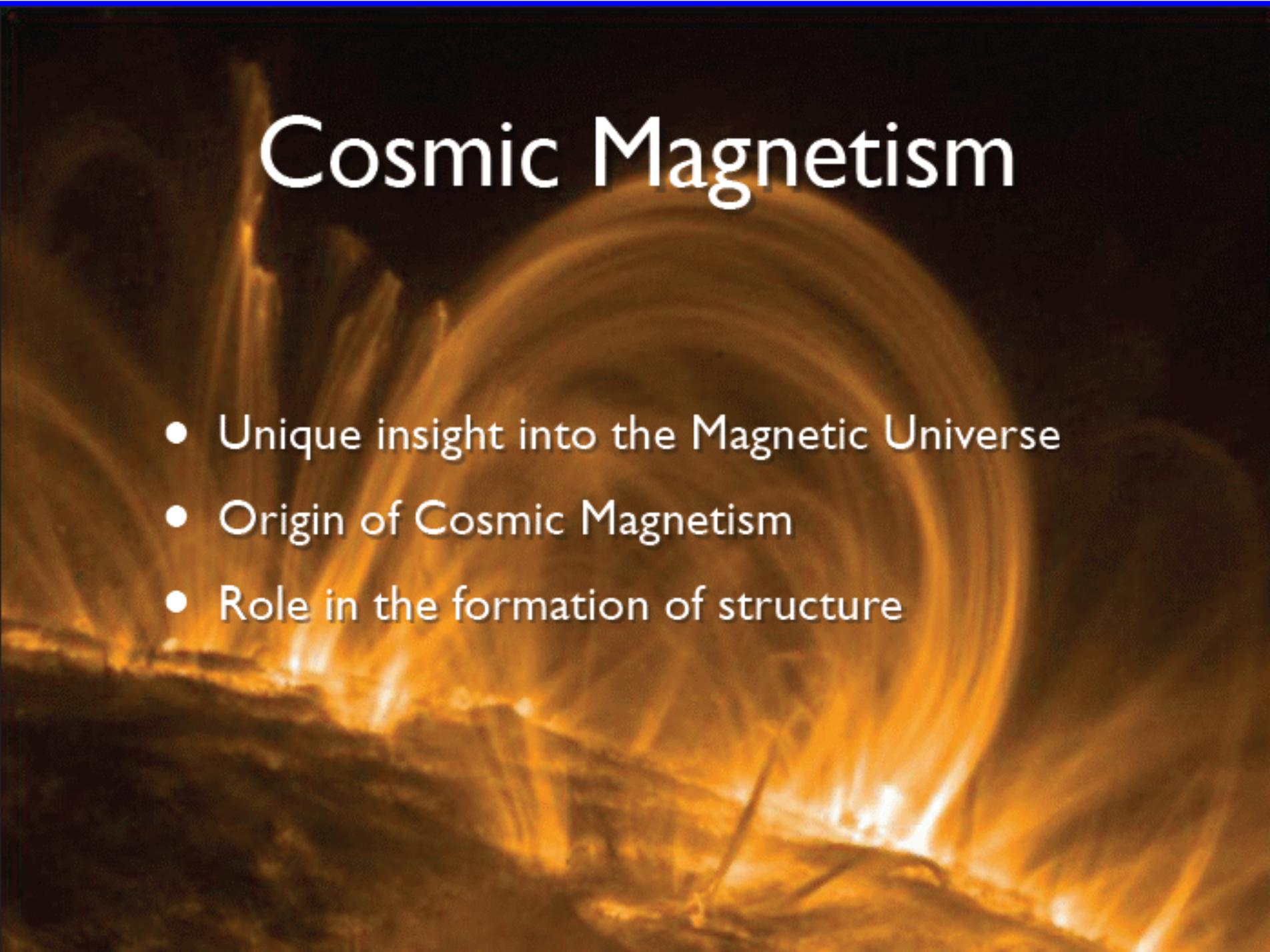
# Galaxy Evolution and Cosmology

- A billion galaxies survey
- Nature of Dark Energy and Dark Matter
- Evolution of the Universe in Gas

# Galaxy Evolution and Cosmology

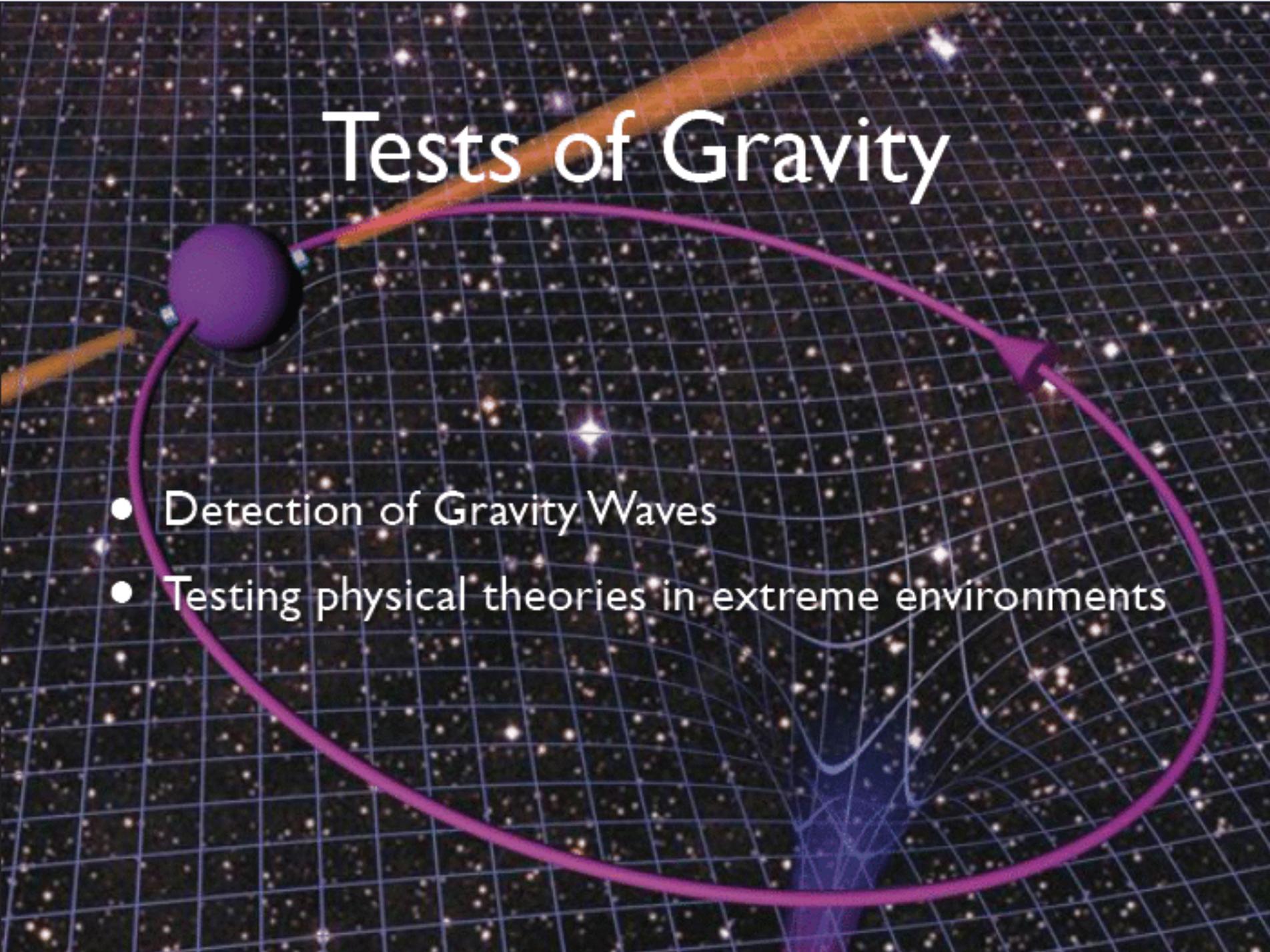
- A billion galaxies survey
- Nature of Dark Energy and Dark Matter
- Evolution of the Universe in Gas

# Cosmic Magnetism

The background of the slide features a dynamic, glowing orange and yellow light pattern, resembling an aurora or a complex magnetic field visualization. A prominent, large, glowing circular structure is centered in the upper half of the image, with several bright, vertical streaks extending downwards from its base. The overall effect is one of intense energy and magnetic activity.

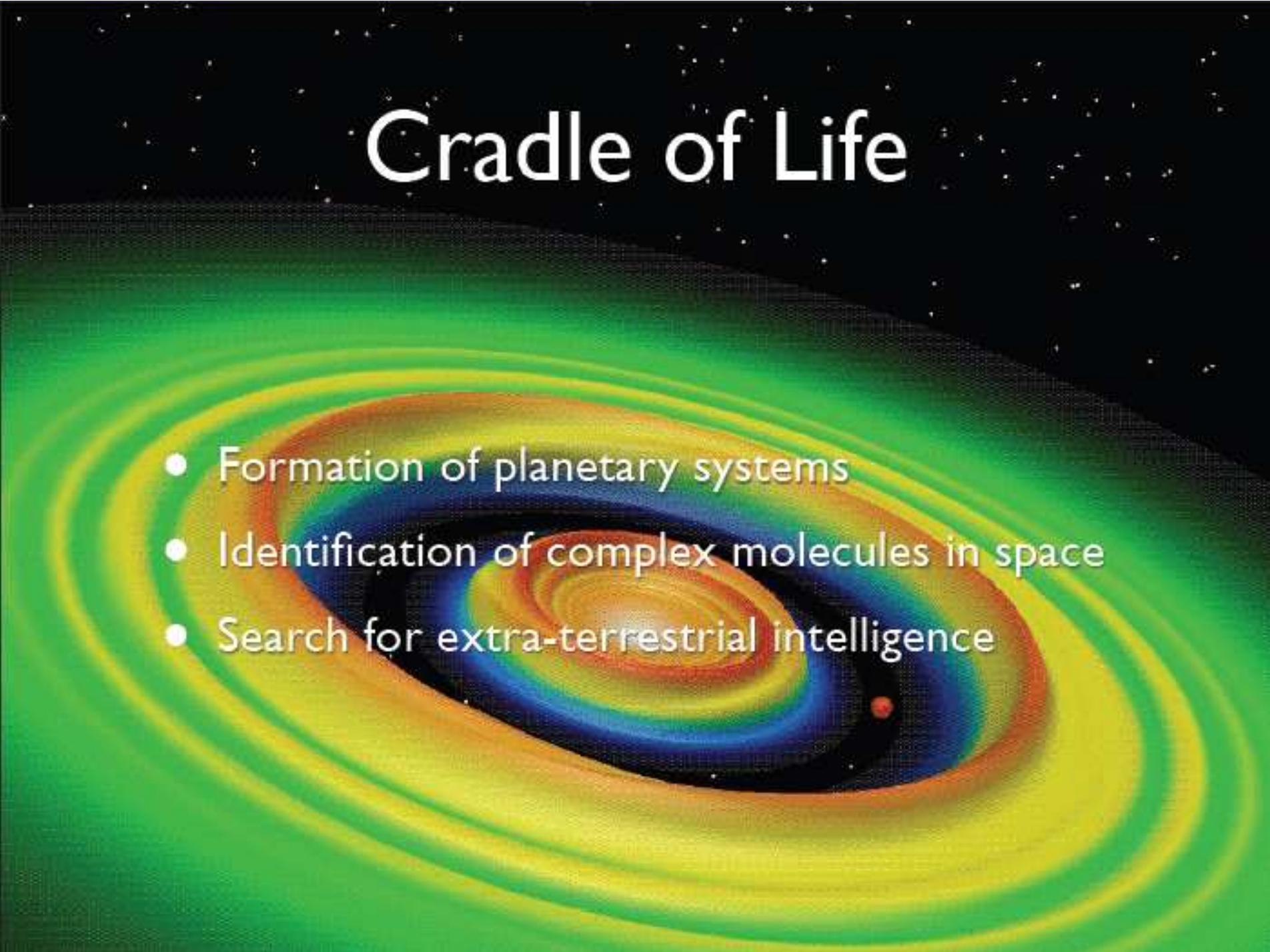
- Unique insight into the Magnetic Universe
- Origin of Cosmic Magnetism
- Role in the formation of structure

# Tests of Gravity



- Detection of Gravity Waves
- Testing physical theories in extreme environments

# Cradle of Life



- Formation of planetary systems
- Identification of complex molecules in space
- Search for extra-terrestrial intelligence



# SKA: the challenge

- A global project from the start: 19 countries, 55 institutes
- Science-driven:
  - Original goal was to detect hydrogen across the Universe
  - Science goals broadened immensely as got community ‘buy-in’
- Technology builds on new developments across the world:
  - Dutch phased arrays, algorithms
  - UK fibre-based data transmission, digital techniques
  - Australian focal-plane arrays
  - US affordable dishes
  - Canadian digital correlators
  - ...etc
- Site either Australia or South Africa
- Estimated cost ~€1.5B

# SKA: the challenge

- Different countries have different science funding cultures
  - E.g. USA cannot formally discuss SKA until it is an ‘approved’ project; this should happen in 2011
  - So, when setting up a decision-making process must keep USA as an involved observer
- Other countries have different approval mechanisms and natural timescales; lining them all up is a major headache
- Does Europe fund the project via individual national contributions or through a central organisation?
  - If the latter, which central organisation?
- How and when should the site decision be taken? Who takes it?
- What is the governance model for the SKA?
- How do we purchase the SKA components? Is price the most important factor? – in which case China and India may win most contracts. Is this acceptable?

# Summary

- Telescopes must always be science-driven.
- Most modern projects are ‘big science’ which, by necessity, entails international collaboration.
- Involvement of and good relations with government officials, politicians and senior university personnel is essential.
- The cost, despite your best estimates, almost always increases.
- The effort and drive needed requires driven and dedicated people