

Radio Stars to Quasars the Cosmic Ray connection

**New Zealand and the beginnings of
Radio Astronomy**

Orewa, New Zealand

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Pasteur

*In the field of observation,
chance favors only the prepared
mind*

Summary

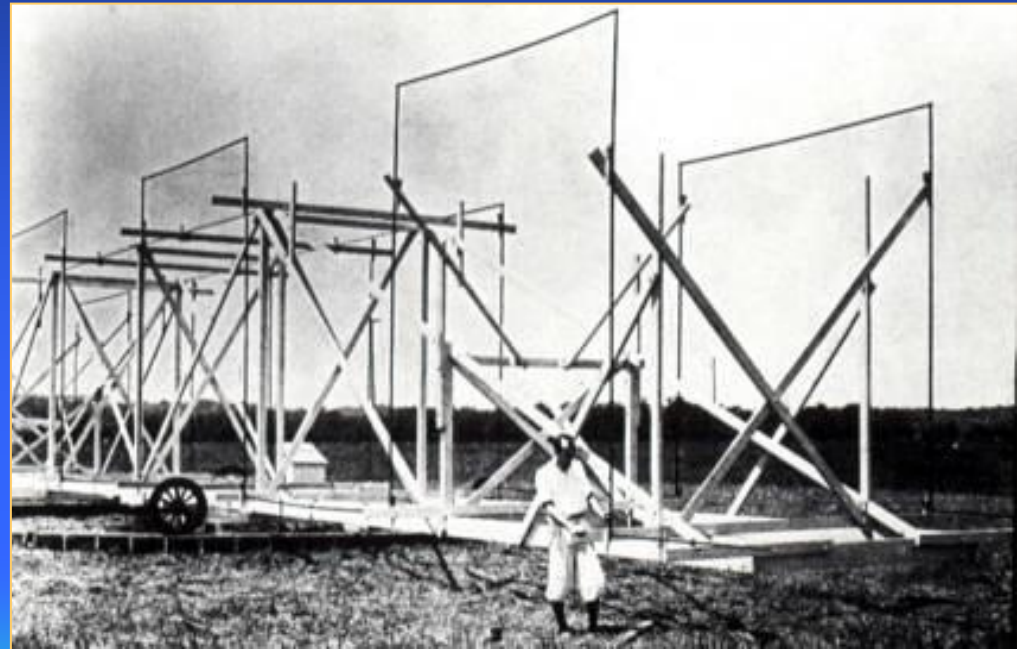
- Examples of how the links between disciplines have forged the process of discovery
- The Viktor Hess centenary meeting in Berlin
 - Hess's discovery of cosmic rays
 - Karl Jansky discovery of cosmic radio emission
 - Striking similarities
- Grote Reber discovers non-thermal emission
- The Synchrotron Radiation mechanism
 - Links radio astronomy and cosmic ray research
 - Ginzburg conference in Moscow
- Discovery of extragalactic active galactic nuclei
- 50 year anniversary of Quasars



Karl Jansky

Bell Telephone Laboratory 1932

- Jansky discovers extraterrestrial radio emission
 - opens a new window on the Universe using radio waves
 - reaction from Bell Labs *“so faint its not even interesting as a source of radio interference!”*
- Not accepted by the astronomical community
- Jansky died in 1950 before the importance of his discovery was appreciated
- No Nobel prize !



- Dec 1938
- Edmond Hamilton
 - *The Cosmic Hiss*
 - Based on Jansky's observation of cosmic hiss
- Extra Terrestrial Intelligence?

Science Fiction

Thanks Gary Tee



1 May 2005



Residual radiation problem

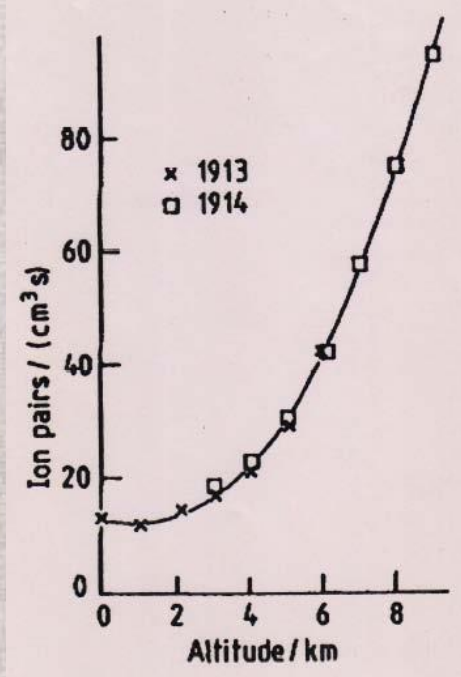
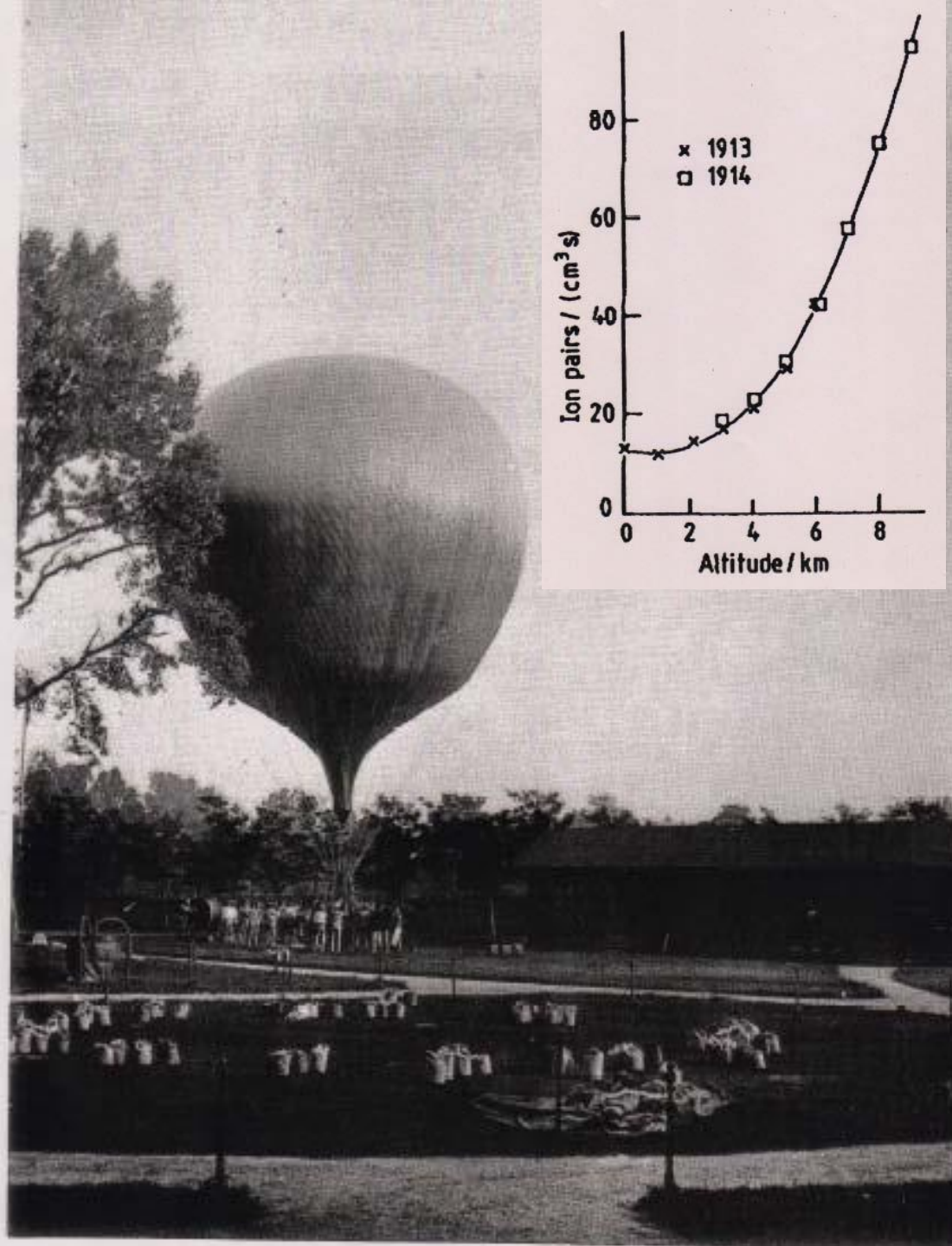
1890's

- In 1896 Becquerel discovered radioactivity by its ionizing effect on an electroscope
- Even well shielded electroscopes were still discharging



Hydrogen Balloon

- Collected scrap iron and combined with sulphuric acid to make the Hydrogen
- Also hydrogen sulphide !
- Hess was a balloonist
- Reached 3.6 km altitude
 - Hess became too sick to go higher
- Radiation increased with altitude



1912 Victor Hess Balloon Flight

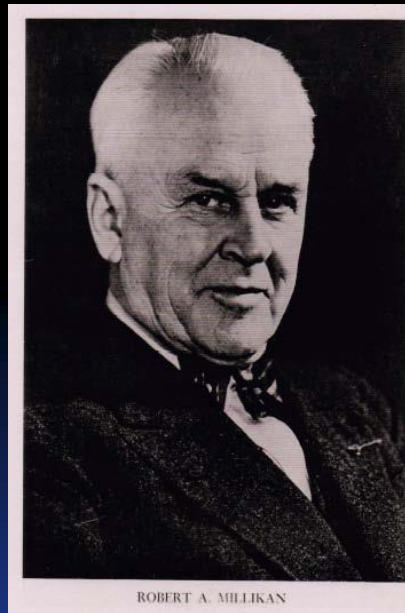


Discovery of Cosmic Rays 1912

- Victor Hess discovered evidence of a very penetrating radiation (cosmic rays) coming from *outside* our atmosphere
- Excluded the sun as a source
- In 1936, Hess was awarded the Nobel prize for this discovery
 - 24 years after the discovery due to the controversy.



In the early 1920's the existence of hohenstrahlung was questioned



ROBERT A. MILLIKAN

- Otis & Millikan
Phys Rev 23, 778 (1924)

Peak (14100 ft). Inside our completely enclosing lead shield, we produce 7.8 ions/cc/sec. The ionization in our apparatus contributed by the walls and the lead shield was found to be at least 7 ions/cc/sec., so that if there were no local radiation on Pike's Peak, the lowest obtainable value of the ionization in our shielded vessel should have been 14.8 ions/cc/sec. We observed as low as 11. We conclude,

therefore, that there exists no such penetrating radiation as we have assumed. Second,

we found as a result of a snow-storm on the mountain as large a percentage change (about 10 per cent) in the ionization inside our 5 cm lead shield as outside it. We interpret this result also as meaning that the whole of the penetrating radiation is of local origin. How such quantities of radioactive material get into the upper air is as yet unknown.



Jansky ↔ Hess



- No equivalent to the *residual radiation*
 - Hence Jansky's role was unambiguous
- Both started a new field of research
- Jansky was an electronic engineer
 - He was not a physicist nor an astronomer
- Hess was an atmospheric electrician
 - He was not a particle physicist nor an astronomer
- Jansky deduced extraterrestrial and from the galaxy
- Hess deduced extraterrestrial and not solar
- Both were ignored or contradicted by the experts
 - No existing framework, wrong time
- Both discoveries were enabled by technology developments
 - Both built and understood their own instruments

Grote Reber's Challenge

- In 1933 Karl Jansky reported the discovery of radio emission from the centre of the Galaxy
- Grote age 21 was a very successful radio ham
- Communicated with amateurs all around the world
- *“no more worlds to conquer”*



The Discovery of the Non-Thermal Universe

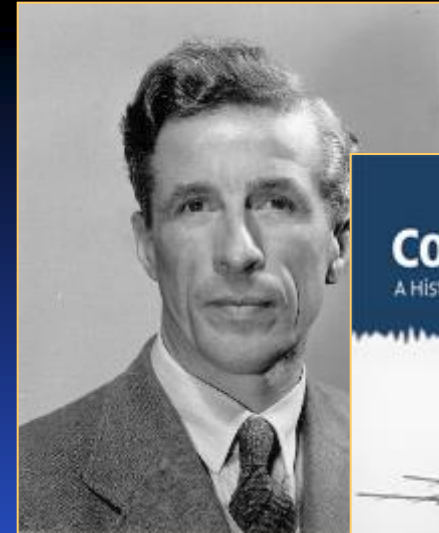
- 1939 detected cosmic static by going to **longer** wavelengths
 - ✗ 3300 MHz
 - ✗ 900 MHz
 - ✓ 160 MHz
- Radiation had to be non-thermal
 - No theoretical basis at the time
 - 1950 Synchrotron radiation theory
 - 10 years after Reber
- First radio map of sky
 - Great difficulty getting published



Cygnus A

strongest radio source in sky

- Hey 1946
 - source with variable intensity
 - time scale of seconds to minutes
 - must be small diameter
 - the first “radio star”
- What was it?
 - no optical counterpart
 - was the whole galactic plane was made of such stars?
 - no theory linking diffuse galactic emission to cosmic rays

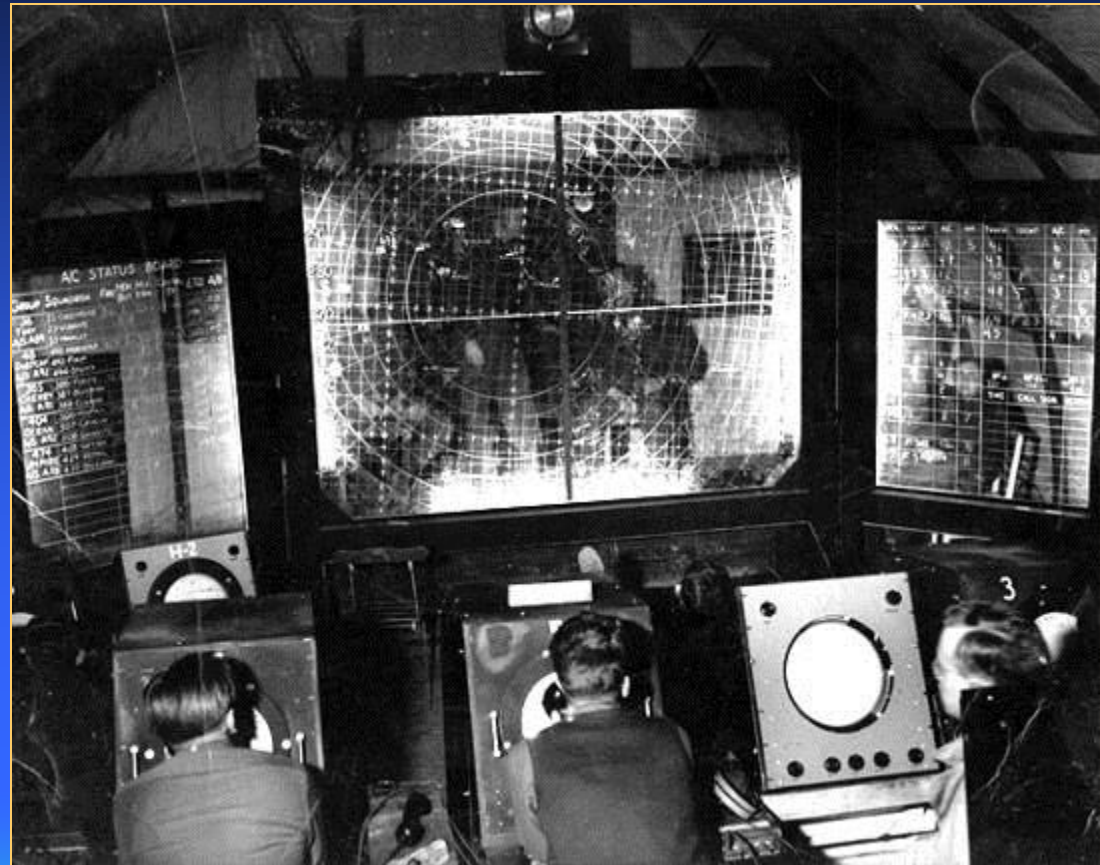
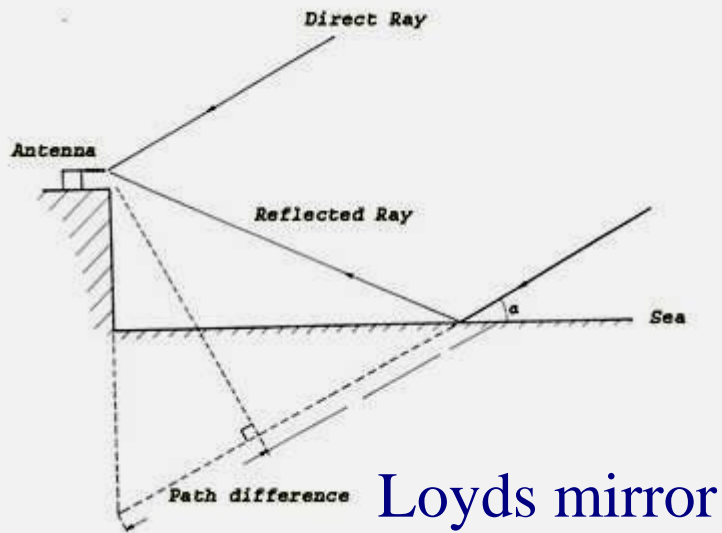


What is the Non-thermal Radio Emission?

- A very confusing story
- Misinterpretation of radio data added to the confusion
 - some radio sources had small diameter (Hey).
 - Hey was correct but it was incorrectly assumed that all radio emission was the sum of these radio stars
 - It was assumed that the radio stars were like the sun
 - this was also incorrect.
 - they were galactic nebula (SNR) and extra galactic (AGN)

What are the Radio Stars? Cliff Interferometer - 1948

- Bolton, Stanley and Slee (CSIRO, Australia)
 - 100MHz Yagi



New Zealand – May 1948

- Bolton and Stanley
 - 100MHz Yagi
- Pakiri Hill near Leigh
- Piha (The Piano)



Positions for Cygnus, Taurus, Virgo, Centaurus



Cliff interferometer CSIRO, Australia - NZ (1948)

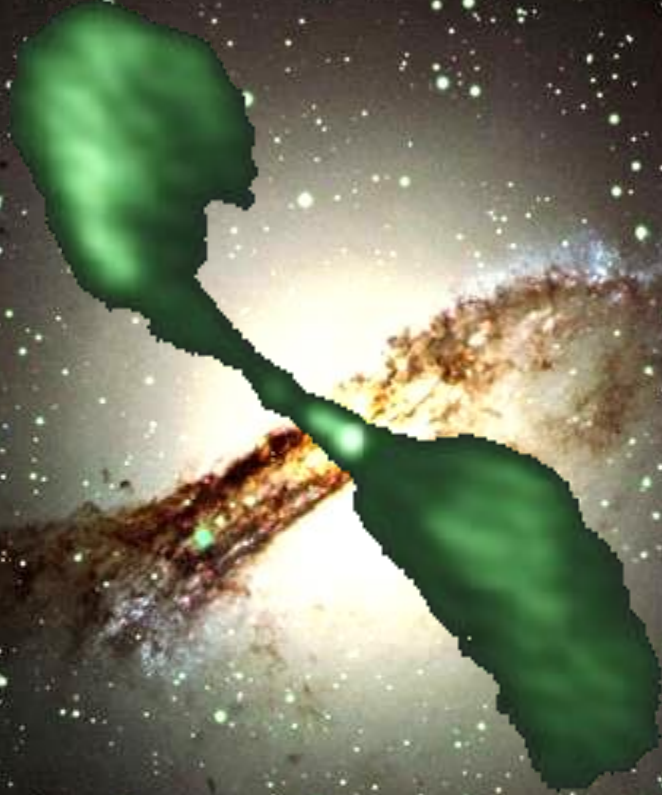
Built to identify the radio stars (John Bolton)

Identification of the Crab Nebula super novae remnant

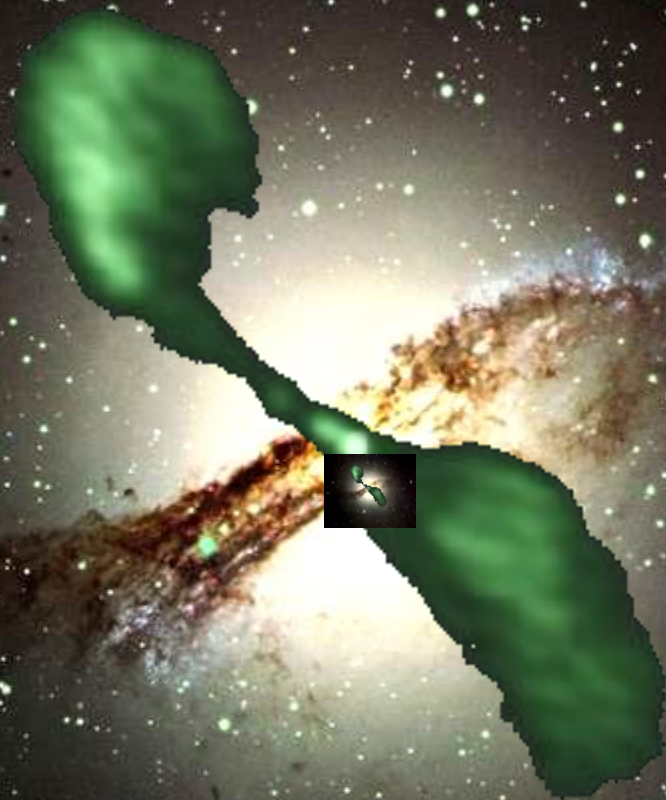
Discovery of extragalactic radio sources at great distances

Centaurus A – NGC5128 and Virgo A – M87

NGC 5128



Centaurus A



Centaurus A

ATCA Mosaic
Feain et al 2011

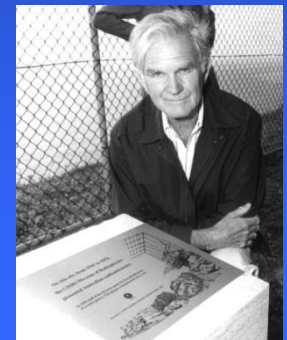
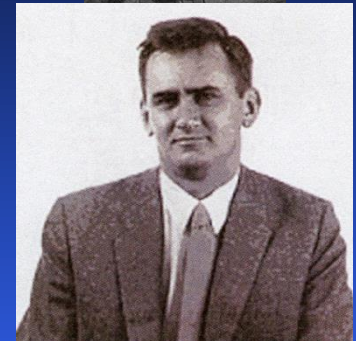


The First Radio Galaxies

- Pre-1949: All radio sources are Galactic stars (radio stars)
- 1949 : The first radio galaxies?

“Positions of Three Discrete Sources of Galactic Radio-Frequency Radiation” - (*Bolton, Stanley, and Slee, Nature 164, 101*)

- Mostly discusses properties of the Crab Nebula
- *NGC 5128 and NGC 4486 (M87) have not been resolved into stars, so there is little direct evidence that they are true galaxies. If the identification of the radio sources are accepted, it would indicate that they are **within our own Galaxy.***



Why was it so difficult to accept extra-galactic?

- Letter from Bolton to Minkowski 20 May 1949

In a letter to Nature (written before I consulted you) I have suggested that these objects may be within our own galaxy - on the basis that a "close freak" is more probable than a large collection of "freaks" at a great distance

- There were no galaxy experts at CSIRO and very few in Australia
- It was easier to assume that the strange galaxies were unusual galactic objects
- There were no known mechanisms to explain the powerful radio emission if extragalactic

Synchrotron Emission

- 1947 Langmuir had observed and explained synchrotron radiation seen in the GE synchrotron
- 1949: Fermi explains the acceleration of cosmic rays particles
 - but no one yet connected this to the radio synchrotron

Synchrotron Model for Radio Emission

- 1949 Unsold: sunspots *anomalous radiation*
 - non-thermal
 - plasma oscillations
- 1950 Alven & Herlofson:
 - synchrotron radiation from sunspots
- 1950 Kiepenhauer (visiting Yerkes)
 - proposed the ISM rather than stars
 - needed magnetic field and high energy charged particles
 - He knew there was evidence for both
 - optical polarization and cosmic rays
- Mostly ignored in the West but enthusiastically embraced in Russia by Ginzburg and Shklovski

Linking non-thermal radio emission and cosmic rays

- 1951 Ginzburg
 - *Synchrotron radiation by relativistic electrons in Galactic Magnetic fields "is very natural and attractive as an explanation for the general radio emissions of the Galaxy"*
- 1953 Shklovski: Crab nebula has radio and optical synchrotron
 - polarization
 - No reference to Ginzburg!
- 1957 Burbidge: M87 jet synchrotron in radio and optical

Cosmic Ray Astrophysics comments by Ginzburg (1996)

- Cosmic ray astrophysics was born in the early 1950s when it became possible to observe cosmic rays far from the Earth.
 - Non-thermal continuum radio emission is from the synchrotron process
 - Crab nebula, and the first radio galaxies identified
 - Because radio waves propagate rectilinearly, the reception of cosmic radio emission provides a tool to obtain information about the electron component of cosmic rays at a distance from the Earth, in our Galaxy, other galaxies, and quasars.
 - *Physics Uspekhi, Volume 39, pp. 155-168 (1996)*

CR now traced at all wavelengths, and directly in gamma rays and UHE cosmic rays.

May 2012

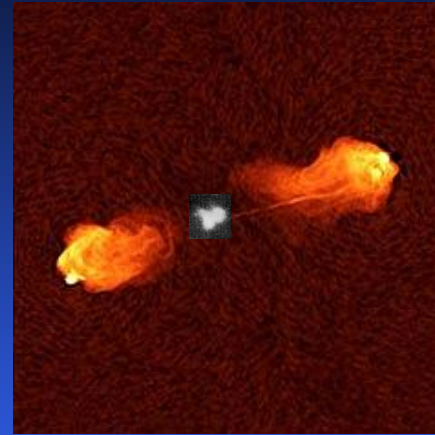
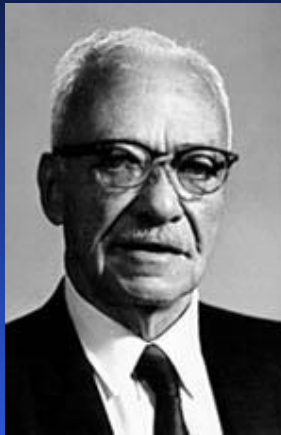


Why was synchrotron radiation not accepted in the West

- Ginzburg (Lebedev Institute) 1953
 - *I at once believed synchrotron radiation was responsible for non-thermal cosmic radio emission. I ascribe this not to any keen insight, but to the fact that I was closer to physics than astronomy....*
 - *The reaction of astronomers was quite the opposite – the synchrotron mechanism seemed mysterious and speculative...*

Radio Galaxies

- All $|b| > 10$ deg radio sources are galaxies (radio galaxies)
 - 1954: Cygnus A (*Baade and Minkowski, ApJ 119, 206*)



- 1955 to 1960: Many new radio galaxies identified
- Starting in 1960 OVRO started to produce accurate positions
 - 3C 295, identified with faint mag 20 galaxy
 - Minkowski measures redshift as $z = 0.46$