Lecture Notes in Physics

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Low Frequency Astrophysics from Space

Proceedings of an International Workshop
Held in Crystal City, Virginia, USA,
on 8 and 9 January 1990

Springer-Verlag
Berlin Heidelberg New York London
Paris Tokyo Hong Kong Barcelona

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ISBN 3-540-52891-1 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-52891-1 Springer-Verlag New York Berlin Heidelberg

Printed in Germany

Printing: Druckhaus Beltz, Hemsbach/Bergstr.
Bookbindung: J. Schäffer GmbH & Co. KG., Grünstadt
2153/3140-543210 – Printed on acid-free paper

PREFACE

Radio astronomers have been working at low frequencies since the first days of the science. However, the observing limitations and the move to ever shorter wavelengths to achieve higher resolution with fixed dish and array sizes has meant that most areas at low frequencies still remain to be fully exploited with modern techniques and instruments. In particular, the possibilities for pursuing the very lowest frequencies with new ground-based arrays, with interferometry from ground-to-space, with Earth-orbiting instruments, and with arrays on the surface of the Moon promises a rebirth of work in this frequency range. Space or Moon-based efforts are particularly enticing since the effects of the Earth's ionosphere are among the major difficulties confronting low-frequency observations. To explore these possibilities further, a workshop devoted to Low Frequency Astrophysics from Space was held on 8 & 9 January 1990 in Crystal City, Virginia. More than fifty participants from all parts of the U.S. and a number of foreign countries outlined a scientific need for a coordinated ground, earth-orbit, and lunar-surface observatory development program to pursue the many areas of astrophysics which can only be probed at low radio frequencies. These astrophysical areas and instrumental concepts are described in these workshop proceedings.

Unfortunately and quite surprisingly, some astronomers tend to regard low frequencies as an area of astronomy where nothing has ever happened in the past and nothing is likely to happen in the future. Besides being a very narrow mind set which disregards the need of modern astrophysics for observations across the entire electromagnetic spectrum, such a view is quite wrong in all respects. As can be seen from Table 1, the past five decades have seen many of the most exciting discoveries in astronomy made at low frequencies. Now, with new instruments, and, particularly, space and lunar initiatives, the field promises a bright future. The participants at the workshop laid out both a challenging list of astrophysical problems to be solved and a series of exciting instrumental concepts to investigate them. Solar astronomy, planetary science, the thermal interstellar medium, supernova remnants, pulsars, interstellar-plasma refractive and diffractive scattering, cosmic rays, old "fossil" electron populations, quasars, radio galaxies, galactic background and halo studies, coherent emission mechanisms, and possible serendipitous discoveries all promise valuable insights at low frequencies. Also, the simple technology and low cost of low-frequency instruments will allow workers to plan relatively inexpensive and very cost effective programs of ground-based arrays, ground-to-space VLBI, Earth-orbit synthesis telescopes, and large mapping arrays on both the near and far sides of the Moon.

A systematic development plan for such instruments has been assembled by the workshop participants and is presented in a very short overview in Table 2, with more discussion in the proceedings. With the technology now available for opening this last unexplored window on the astrophysics of the Universe, a phased program of ground-based and ground-to-space VLBI observations at frequencies above 10 MHz, and orbiting and lunar-based observatories at lower frequencies, should proceed at once. The 10 and 30 MHz ground-based arrays should be in operation before the next solar minimum and, because of the long lead times for space missions, planning for space-to-ground, Earth-orbit, and lunar arrays should be initiated. Ground-based arrays can also serve as test beds for the hardware and software of space missions. In particular, lunar-array deployment over large areas with remote operation will require extensive ground-based testing. Also, software development of large-field-of-view mapping techniques will be needed for both ground-based and space-based arrays.

In all, the meeting provided a stimulating atmosphere for the exchange of ideas and for the discussion of important scientific possibilities which have too long been ignored by many in the astronomical community. This volume reports these efforts to bring to an end the years of unfortunate neglect of an exciting area of astrophysics.

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May 1990

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Table 1: Significant Discoveries in Radio Astronomy at Low Frequencies

Year(s)	Frequency	Discoverer(s)	Short Description
1931-35	20 MHz	Jansky	Discovery of cosmic radio waves: Birth of radio astronomy
1935-40	160 MHz	Reber	First spectrum of galactic background
1940	160 MHz	Henyey, Keenan	Interpretation of Reber's observations requires new nonthermal emission processes
1942	60 MHz	Hey	First detection of solar radio emission
1946	60 MHz	Hey	Meteor stream radiants from radio reflection methods
1946	175 MHz	Ryle et al.	First two element interferometer: Resolved sunspots; defined basic principles of aperture synthesis
1947	200 MHz	Pawsey et al.	Sea interferometer used to resolve sunspots
1946-50	50-150 MHz	Ryle, Hey, Bolton, others	First discoveries of discrete cosmic radio sources (Cyg-A)
1951	50-150 MHz	Ryle, Smith, Baade, Minkowski, Mills, others	Discovery of radio emission from SNRs (Cas-A, Crab Nebula)
1951	50-150 MHz	Ryle, Smith, Baade, Minkowski, Mills, others	Discovery of radio galaxies (Cyg-A, Vir-A, Cen-A, Her-A)
1951	158 MHz	Brown, Hazard	Discovery of radio emission from normal spirals (M31)
1952-53	400 MHz	Mills	First large interferometer: The Mills Cross
1955	85 MHz	Mills	First detection of radio emission from the Magellanic Clouds

Table 1:
(Cont.)

1955	50-250 MHz	Kraus, Mills, Baldwin, others	First all-sky surveys with interferometers
1955	22 MHz 18 MHz	Burke, Franklin Shain	First detection of planetary radio emission (Jupiter)
1955-63	50-200 MHz	Hewish, Vitkovich, Slee, Parker, Högbom	First use of IPS to study the solar corona
1959	400 MHz	Drake and Hvatum, Roberts and Stanley	Evidence for synchrotron emission from Jupiter
1960	50-400 MHz	Blaauw, Gumm, Oort, others	New definition of galactic coordinates based on interpretation of low frequency surveys
1962-63	178 MHz	Bennett	First widely used radio catalogue (3C)
1963	178 MHz	Clark, Hewish	First use of IPS for size limits on compact radio sources
1963	136 MHz 410 MHz	Hazard et al. Schmidt, Sandage Greenstein, others	Discovery of quasars (3C273)
1967	18 MHz	Brown, Carr, Block	First VLBI fringes
1968	85 MHz	Bell, Hewish	Discovery of pulsars -- Nobel Prize

Table 2: Programs for Development of Low Frequency Radio Astronomy

Concept	Institutions*	Freq. Range	Short Description
LFVLA (+ VLBA outriggers)	NRAO/NRL	10, 30, 75 MHz	The VLA is currently outfitted with prime focus, 75 MHz dipoles on 4 antennas. Construction is underway to outfit 4 more. Testing and development can be carried out on these with plans being developed for a full 27 element array at 75 MHz. After that, consideration can be given to fully outfitting the VLA and nearby VLBA stations at 10, 30, and 75 MHz.
OLFRAS	NRL/GSFC/ JPL/NMSU	1, 5, 13, 30, 75 MHz	A single satellite in elliptical orbit (~300-3000 km altitude) would work in conjunction with ground based arrays for OVLBI synthesis mapping in the 10-75 MHz range. Interference monitoring could be carried out in the 1-30 MHz range.
LORAE	NMSU/JPL/ NRL/GSFC	15 kHz to 30 MHz	LORAE would be a hitchhiker on the Lunar Observer with one or more low frequency dipoles on one or more orbiters. It would carry out three tasks -- 1. interference monitoring at the lunar distance, 2. occultation mapping of bright sources, and 3. all sky, low resolution surveying.
LFSA	NRL/JPL/ GSFC/NMSU	1, 5, 13, 26 MHz	The LFSA would be an orbiting array in high earth orbit to carry out all sky surveying and high resolution full synthesis mapping of sources in the deka-hectometer wavelength range.
Near Side Lunar Array	GSFC/JPL/ NMSU/NRL/ UTX	150 kHz to 30 MHz	In conjunction with the establishment of the first lunar outpost, it would be possible to place and operate a low frequency array on the lunar near side.
Far Side Lunar Array	GSFC/JPL/ NMSU/NRL/ UTX	150 kHz to 30 MHz	As human presence on the Moon becomes routine and communication links are established from the back side of the Moon to Earth, lunar far side radio astronomy would become possible.

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*Only a few institutions are listed as presently developing initial concepts. Actual programs will certainly involve international cooperative efforts by many more institutions.

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