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ASTRONOMY PROGRAM

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March 16, 1983

Ms. Genevieve E. Wiseman
Grants Officer
National Aeronautics and Space
Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

SUBJ: Final close-out of NASA Contract
NSG 5320
Principal Investigator: Prof. M. R. Kundu

Dear Ms. Wiseman,

Please find enclosed my final technical report on NASA Contract NSG 5320 "Ground Based Solar Radio Observations During SMM". No equipment has been purchased on the contract. My technical report contains the list of publications that have come out of research carried out under this contract. The Cumulative Cost Expenditure Report will be furnished by our Contracts and Grants Office.

If you have any further questions, please do not hesitate to contact me at (301) 454-3005.

Yours sincerely,

M. R. Kundu

M. R. Kundu
Professor and Director
Astronomy Program

MRK/eb

Enclosure

cc: Dr. D. Bohlin

NSTIF
Mr. Bullock/602

Final Report on NASA Contract NSG 5320

"Ground Based Solar Radio Observations During Solar Maximum Mission"

Principal Investigator: Prof. M. R. Kundu

Since the start of the present NASA contract we have made extensive use of the existing large radio telescopes as well as our own Clark Lake Radio Observatory's telescope for observations of solar flares and active regions. The observations have been made individually and in coordination with the SMM experiments. These observations are briefly described below.

Research at Centimeter Wavelengths

The Very Large Array (VLA) of the NRAO and the Westerbork Synthesis Radio Telescope (WSRT) have been used extensively for making aperture synthesis maps of solar active and flaring regions with resolutions as good as ~ 1" arc. Observations of the Flare buildup in the form of increased intensity and increased polarization have been made with the VLA and WSRT in coordination with the XRP and UVSP experiments aboard SMM.

Burst sources have been observed and their position, intensity and polarization as a function of time with resolution of ~ 1" arc have been measured, in coordination with the SMM XRP, UVSP, HXRBS and HXIS experiments. All together we have observed more than 40 flares, either along with the SMM experiments or by themselves. Only a part of the observations has been analyzed and several papers has been published.

We have observed slowly varying active regions, flare buildup and burst activity at 2, 6 and 20 cm wavelengths. Our observations of bursts have shown the predominance of bipolar structures, indicating that the

radiating electrons are trapped in magnetic loops. In particular, we find that at 6 cm wavelength the impulsive energy release occurs in arcades of loops and the burst emitting region is located near the tops of the loops and occupies a significant fraction of both sides of the legs of the loops. In multiply spiked bursts the constancy of the source location implies repeated acceleration of the electrons in the same magnetic trap. In some long lasting microwave continuum events (type IV) occurring near the limb, we have provided the first evidence that the microwave emitting electrons are located in post flare loops, the burst source ascending through the corona with a speed of 20-30 km/sec.

In the case of a large flare observed simultaneously in UV and hard X-rays, the VLA pre-flare maps show gradual pre-flare buildup in intensity and circular polarization. For the first time, we have observed a reversal in polarization of a bipolar feature indicating either an emergence of new flux or a change in the topology of the magnetic field. In another large burst, the onset of an impulsive burst is accompanied by a change in orientation of the neutral plane, suggesting the interaction two or more magnetic loops responsible for the impulsive energy release; near the impulsive peak we have observed a unique quadrupole structure which implies that the impulsive energy release is triggered by two interacting bipolar loops with opposite field lines at the loop tops.

Our observations of active regions simultaneously in microwaves and soft x-rays have shown the importance of magnetic field in the generation of active region emission at 6 cm wavelength. The densities and temperatures derived from the x-ray spectroheliograms indicate that bremsstrahlung does not compete significantly with gyro-resonance absorption in making the active region sources optically thick. We

conclude that cyclotron emission occurs at the 3rd harmonic of the gyro-frequency, implying 600 G fields at coronal levels.

We have detected for the first time, using the WSRT, ring structure in 6 cm sources associated with sunspots. Using the SMM XRP data we have interpreted the ring structure as due to the existence of cool material above the spot, although the geometrical (angle) effect of gyro-resonance absorption could not be excluded. We are now performing model computations to explain the total intensity and polarization structures of a continuous set of active region maps produced with the WSRT at 6 cm with a resolution of 3" arc. Using the WSRT data we are also studying homologous flares at 6 cm and interacting loops as 6 cm burst sources.

Meter-Decameter Wavelengths

The University of Maryland Clark Lake Radio Observatory telescope consists of an array which has been used in the form of two (E-W and N-S) one-dimensional swept-frequency grating interferometers in the frequency range 10-125 MHz. With this system we have been able to do the following studies: Positional measurements of radio bursts in coordination with two SMM experiments, the C/P and HXRBS. Large bursts - type II and type IV are particularly suitable for studies of the coronal transient events as recorded by the C/P, while the type III burst positions and structures are relevant for studies of hard x-ray bursts as recorded by the HXRBS. To date we have observed several important bursts (type II/type IV) and a large number of type III's for coordinated studies with the C/P and HXRBS experiments respectively. These observations are being analyzed now, and some papers have been published.

The following publications have resulted from the research funded by this contract:

1. "Observations with the VLA of a Stationary Loop Structure on the Sun at 6 Centimeter Wavelength", M. R. Kundu and T. Velusamy, Astrophys. J., 240, L63, 1980.

2. "VLA Observations of Post Flare Loops at 20 cm Wavelength", T. Velusamy and M. R. Kundu, Astrophys. J., 243, L103, 1981.

3. "VLA Observations of Positions of 6 Centimeter Burst Peaks Associated with Hard X-ray Burst Spikes", M. R. Kundu, M. Bobrowsky and T. Velusamy, Astrophys. J., 252, 342, 1981.

4. "Magnetic Structure of a Flaring Region Producing Impulsive Microwave and Hard X-ray Bursts, M. R. Kundu, E. J. Schmahl, and T. Velusamy, Astrophys. J. 253, 963, 1982.

5. "VLA Observations of the Evolution of a Solar Burst Source Structure at 6 Centimeter Wavelength", T. Velusamy and M. R. Kundu, Astrophys. J., 258, 388, 1982.

6. "Radio Imaging of Solar Flares Using the Very Large Array: New Insights Into Flare Process", M. R. Kundu, E. J. Schmahl, T. Velusamy and L. Vlahos, Astron. Astrophys., 108, 188, 1982.

7. "Flare Buildup in X-rays, UV, Microwave and White Light", E. J. Schmahl, "Advances in Space Research" (in press), 1983.

8. "Physics of the Impulsive Phase of Solar Flares", M. R. Kundu, "Advances in Space Research", (in press), 1983.

9. "Active Region Magnetic Fields Inferred From Simultaneous VLA Microwave Maps, X-ray Spectroheliograms, and Magntograms", E. J. Schmahl, M. R. Kundu, K. T. Strong, R. D. Bentley, J. B. Smith, Jr. and K. R. Krall, Solar Phys., 80, 233, 1982.

10. "Observations of Ring Structure in a Sunspot Associated Source at 6 cm Wavelength", C. E. Alissandrakis and M. R. Kundu, Ap. J. Letters, 253, L49, 1982.

11. "VLA Solar Observations of a Remote Microwave Brightening Following a Flare", M. R. Kundu, D. M. Rust, and M. Bobrowsky, Ap. J., 265, 1084, 1982.

12. "X-ray and Microwave Observations of Active Regions", D. F. Webb, J. M. Davis, M. R. Kundu and T. Velusamy, Solar Phys., 1982 (in press).

13. "VLA Observations of a Solar Active Region and Coronal Loops", D. McConnell and M. R. Kundu, Ap. J., June 15, 1982.

14. "A Study of the Evolution of Energetic Electrons in a Solar Flare", G. D. Holman, M. R. Kundu and B. R. Dennis, Ap. J. (submitted), 1983.

15. "Microwave, Soft and Hard X-ray Imaging Observations of Two Solar Flares", M. R. Kundu, M. Machado, et al., Astronomy and Astrophysics (submitted), 1983.

16. "Interpretation of Microwave Active Region Ring Structure and other Features Using SMM Soft X-ray Observations", K. T. Strong, C. E. Alissandrakis and M. R. Kundu, Ap. J. (submitted), 1983.

17. "Radio and Visible Light Observations of a Coronal Arcade Transient", T. E. Gergely, M. R. Kundu et al., Solar Phys. (submitted), 1983.

18. "Spatial Characteristics of Microwave Bursts", M. R. Kundu, Proc. U.S.-Japan Seminar, "Recent Advances in the Understanding of Solar Flares", (in press), 1983.

19. "VLA Observations of Solar Radio Bursts at Centimeter Wavelengths", M. R. Kundu, Invited Talk, SMY Workshop, Crimea, USSR, March 24-28, 1981.

20. "VLA Observations of Solar Flares and Tests of Flare Models", M. R. Kundu, Solar Physics Division/AAS Special Session, Invited Talk, Jan. 11-14, 1982, Boulder, B.A.A.S., 13, 909, 1981.

21. "Center to Limb Variation of a Sunspot Associated Microwave Source: Evidence of Currents in Coronal Loops, C. E. Alissandrakis and M. R. Kundu, Astron. and Astrophys. (submitted), 1983.

Abstracts of Papers Presented At Meetings

1. "VLA Observations of the Impulsive Phase of the June 25, 1980 Flare at 6 cm Wavelength", M. R. Kundu, T. Velusamy and E. J. Schmahl, B.A.A.S. 12, 901, 1980.

2. "VLA Observations of a Centimeter Wavelength Burst Associated with a Filament Eruption on May 14, 1980", T. Velusamy and M. R. Kundu, B.A.A.S., 12, 901, 1980.

3. "Comparison of VLA Microwave Maps of Active Regions wih X-ray Spectroheliograms", E. J. Schmahl, M. R. Kundu, K. T. Strong and XRP Team, B.A.A.S., 12, 907, 1980.

4. "Radio and Visible Light Observations of a Coronal Transient Associated with a Prominence Eruption", T. E. Gergely, M. R. Kundu, F. T. Erskine, C. Sawyer, W. J. Wagner, R. Illing, L. L. House, M. K. McCabe, R. T. Stewart and G. J. Nelson, B.A.A.S., 12, 900, 1980.

5. "VLA Observations of Two SMM Flares at 6 cm", F. T. Erskine, M. R. Kundu and T. Velusamy, B.A.A.S., 12, 901, 1980.

6. "Correlated Soft X-ray and Microwave Observations of Active Region Loops", D. F. Webb, J. M. Davis, M. R. Kundu and T. Velusamy, B.A.A.S., 12, 916, 1980.

7. "Nonthermal Flare Emission and the Nonlinear Dynamics of High Energy Electrons", G. D. Holman, K. Papadopoulos, and M. R. Kundu, B.A.A.S., 12, 901, 1980.

8. "VLA Observations of Large Scale Microwave Brightening Following a Flare", M. Bobrowsky, M. R. Kundu, D. M. Rust, B.A.A.S., 13, 846, 1981.

9. "Flare Buildup at 6 cm Wavelength, in UV and Hα", E. J. Schmahl, and M. R., Kundu, B. Woodgate and R. Shine, B.A.A.S., 13, 846, 1981.

10. "Gyrosynchrotron Masering in Solar Flares", P. J. Morrison, G. D. Holman and M. R. Kundu, B.A.A.S., 13, 860, 1981.

11. "Active Region Magnetic Fields", J. B. Smith, Jr., K. T. Strong,. E. J. Schmahl, M. R. Kundu, K. R. Krall, and R. D. Bentley, B.A.A.S., 13, 881, 1981.

12. "Observations of Flare Buildup at 6 cm Wavelength using the VLA", M. R. Kundu, SMY-FBS Workshop, NASA-GSFC, Feb. 1981.

13. "Simultaneous VLA Observatiaons of the Impulsive Phase of a Flare at 2 and 6 cm Wavelengths", M. R. Kundu, SMY Workshop at Annecy, France, Oct. 25-31, 1981.

14. "VLA Observations of Flare Buildup at 6 cm Wavelength", M. R. Kundu, SMY Workshop, Annecy, France, Oct. 25-31, 1981.

15. "Correspondence Between 6 cm and Optical Images of a Solar Active Region", D. McConnell, E. J. Schmahl and M. R. Kundu, B.A.A.S., 14, 921, 1982.

16. "VLA Observations of Dramatic Changes in Fine Structure of Solar Active Regions", E. J. Schmahl, D. McConnell and M. R. Kundu, B.A.A.S., 14, 922, 1983.

Meetings and Workshops

The Principal Investigator attended the Annecy (France) SMY Workshop in October, 1981, where he was the group leader of the Impulsive Phase team. He also attended the SMY workshop in Crimea (USSR) in March, 1981, where he presented an invited talk. He presented an invited review talk at the Solar Maximum Year Symposium, Ottawa (Canada), May 1982. He presented the U.S.-Japan Seminar on "Research Advances in the Understanding of Solar Flares", Tokyo (Japan), October 1982. He also

presented an invited talk at the ASS-Solar Physics Division Special Session, Boulder, Colo., January 1982. He has been codirecting the three SMM workshops being held at NASA-GSFC, January, June and December 1983.

Drs. Gergely, Holman and Schmahl attended the SMY workshop in Annecy (France) in October 1981, and the SMY Symposium in Ottawa (Canada), May 1982 and presented invited talks at these meetings.

Invited Talks

"VLA Observations of Solar Radio Bursts at Centimeter Wavelengths", M. R. Kundu, Invited Talk, SMY Workshop, Crimea, USSR, March 24-28, 1981.

"VLA Observations of Solar Flares and Tests of Flare Models", M. R. Kundu, Solar Physics Division/ASS Special Session, Invited Talk, Jan. 11-14, 1982, Boulder, B.A.A.S., 13, 909, 1981.

"Physics of the Impulsive Phase of Solar Flares", M. R. Kundu, in Advances in Space Research, in press, 1983.

"Spatial Characteristics of Microwave Bursts", M. R. Kundu, Proc. U.S.-Japan Seminar, "Recent Advances in the Understanding of Solar Flares", (in press), 1983.