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"ANALYSIS OF OGO-5 AND OSO-7 X-RAY DATA"

Grant NGR 05-002-294

FINAL REPORT

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ABSTRACT

The research carried out under this grant is summarized with emphasis on the physical nature of solar flares implied by the data. The empirical results were obtained primarily from the OGO-5 and OSO-7 X-ray data in combination with optical data. The principal conclusions regarding the physics of flares are the following.

1. Flares are produced by magnetic field reconnection.
2. The resulting thermal X-ray plasma is cooled primarily by heat conduction rather than by radiative cooling.
3. The heating and cooling of the thermal X-ray plasma are approximately in balance during the maximum phase of the flare.

The objectives of the research supported by this grant were the following.

A. To compare X-ray observations of solar flares with optical and radio observations of same.

B. To derive models of the physical nature of solar flares from the above data.

The most significant research accomplished under this grant was based directly on the comparison of X-ray and optical data and only indirectly on radio data. As can be seen from the following paragraphs, a consistent physical model for the thermal phase of flares has emerged from this research.

Using data from the OGO-5 and OSO-7 X-ray experiments, J.-R. Roy and F. Tang studied flares in which filament disruption observed in Hα was accompanied by slow thermal X-ray bursts. Certain phases of the filament evolution were found to correspond to definite stages in the time profile of the X-ray flux. This correspondence implies that rapid changes in the magnetic field threading the filament occur during the energy release which produces the thermal X-ray plasma. It was also found that these data favored conduction cooling over radiative cooling of the thermal X-ray plasma. This study is described and discussed in detail in the enclosed report (BBSO #0141) which has been submitted to _Solar Physics_.

From the UCSD OSO-7 X-ray data, J.-R. Roy and D.W. Datlowe (UCSD) analyzed the physical parameters of 37 X-ray bursts associated with solar flares occuring behind the solar limb. They found that the over-the-limb events were indistinguishable from the disk events in terms of maximum temperature, maximum emission measure and characteristic cooling time of the thermal X-ray plasma. However, the spectrum of the non-thermal X-rays at the time of maximum flux of hard ($\gtrsim$ 20 keV) X-rays was found to be steeper (softer) for the over-the-limb events than for events near the center of the disk. In addition, they found empirical evidence that the thermal X-ray plasma is cooled predominantly by heat conduction rather than by radiation. This work is presented in detail in the enclosed report (BBSO #0143) which has been accepted for publication in _Solar Physics_.

J.-R. Roy and D.M. Rust (Sacramento Peak Observatory) analyzed OSO-7 soft and hard X-ray data in conjunction with Hα, continuum light and magnetographic data for two CINOF flares (2220 UT June 23, 1972 and 1918 UT June 24, 1972).

The first flare was slow and "cool" ($T_{max} = 1.3 \times 10^7$°K) and had no hard X-ray burst, while the second flare was impulsive and "hot" ($T_{max} = 2.3 \times 10^7$°K) and had a strong hard X-ray burst. In both of these flares, they concluded from the data that the thermal X-ray plasma is cooled by heat conduction rather than by radiative cooling. These results were presented by D.M. Rust at the Joint IAU-COSPAR Symposium on Solar γ-, X- and EUV Radiation, Buenos Aires, 11-14 June, 1975, and will appear in the published proceedings of that symposium.

R.L. Moore and D.W. Datlowe (UCSD) studied the heating and cooling of the thermal X-ray plasma in 17 solar flares by estimating heating and cooling times from the temperatures and emission measures derived from OSO-7 data and from the over-all length scales estimated from Hα filtergrams of the same flares. The heating was assumed to be due to magnetic field reconnection and the cooling was assumed to be due to heat conduction and radiation. Comparison of the empirically estimated heating and cooling times indicates that flares are in fact produced by magnetic field reconnection and that the cooling of the thermal X-ray plasma is dominated by heat conduction. R.L. Moore studied the implications of the same data with regard to the process of magnetic field reconnection. He found that the empirical evidence indicates that the rate of reconnection is controlled by the Alfven speed within the reconnection region rather than by the Alfven speed far outside the reconnection region. This result favors the reconnection model of Parker (1973, Astrophys. J. 80, 247) over that of Petschek (1964, in N.W. Hess (ed.) AAS-NASA Symposium on the Physics of Solar Flares). The results outlined in this paragraph were presented by R.L. Moore at the AAS Meeting at Rochester, New York, August 20-23, 1974 and at the Meeting of the Solar Physics Division of the AAS at Boulder, Colorado, January 20-22, 1975, and are currently being prepared for publication.

In summary, the results of research carried out under this grant indicate the following physical picture for the thermal X-ray flare.

1. The flare energy is stored in the non-potential preflare magnetic field configuration and is released through changes in this configuration.
2. The changes in the magnetic field and the accompanying energy release are accomplished by reconnection of the magnetic field. In particular, the heating of the thermal X-ray plasma is controlled by the reconnection process.

3. The reconnection heating of the thermal X-ray plasma is balanced primarily by conduction cooling rather than by radiative cooling.
4. The rate of reconnection, and hence the rate of heating, is controlled by the Alfven speed in the reconnection region.

Publications Resulting from the Research Supported by this Grant (NGR 05-002-294)

Roy, J.-R. and Datlowe, D.W.: "X-Ray Bursts from Solar Flares Behind the Limb", BBSO #0143 (Accepted for publication in Solar Physics.)

Roy, J.-R. and Tang, F.: "Slow X-Ray Bursts and Chromospheric Flares with Filament Disruption", BBSO #0141 (Submitted to Solar Physics.)

Rust, D.M. and Roy, J.-R.: "The 'CINOF' Flares of McMath Regions 11930 (2220 UT June 23, 1972) and 11918 (1918 UT June 24, 1972)" (To appear in the Proceedings of the Joint IAU-COSPAR Symposium on Solar γ-, X- and EUV Radiation, Buenos Aires, 11-14 June, 1974.)

Moore, R.L. and Datlowe, D.W.: "Heating and Cooling of the Thermal X-Ray Plasma in Solar Flares" (To be published.)

Moore, R.L.: "Magnetic Field Reconnection in Solar Flares: Implications of Recent Observational Evidence" (To be published.)