SESSION II: SOLAR FLARES

THE SUN AS A FLARE STAR: X-RAY SPATIAL AND PLASMA PROPERTIES DERIVED FROM A SOLAR ECLIPSE OBSERVED BY GOES

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The size, location, and flux of four solar soft X-ray sources, including a flare, were derived from the disk-integrating GOES X-Ray Sensors during a solar eclipse. The fluxes were used to derive the temperatures and emission measures of these sources. If an incorrect amount of flux is attributed to the flare source, then the evolution of these derived plasma properties seems unphysical.

Introduction

A solar eclipse was observed by one of the operational GOES satellites on 1987 October 22 at ~1100 UT. From 1055 to 1128 UT, the moon passed between the sun and the GOES 6 satellite, while GOES 7 did not experience an eclipse. During the eclipse, a small, B9 flare was in progress. This flare was observed at each satellite by identical disk-integrating X-Ray Sensors (XRS) with nominal bandpasses of 1-8 and 0.5-4 Å. The solar panel currents from each satellite serve as full sun, optical sensors. These data have been used to derive the location, size, and flux of four solar X-ray sources. These fluxes were then used to derive the temperature and emission measure for these sources and for the flare. These data provide the unique opportunity to examine the validity of assumptions regarding the fraction of the total observed solar flux that arises from the flare. This fraction is related to the filling factor, a measure of how much of the volume is filled with flaring plasma.

Derivation of Spatial Properties

The solar panel current and X-ray fluxes were modeled to derive the spatial properties of the solar sources. All sources were assumed to be disks of uniform flux that, except for the flare source, were constant in time. The area of a source occulted by the moon is given by

$$A(t) = \int_{x_s(t)}^{R_s} (R_s^2 - x^2)^{1/2}\,dx + \int_{x_m(t)}^{R_m} (R_m^2 - x^2)^{1/2}\,dx \tag{1}$$

$$\begin{aligned} &= \pi/2\, R_s^2 - R_s^2 \sin^{-1}[x_s(t)/R_s] - x_s(t)\,[R_s^2 - x_s^2(t)]^{1/2} + \\ &\quad \pi/2\, R_m^2 - R_m^2 \sin^{-1}[x_m(t)/R_m] - x_m(t)\,[R_m^2 - x_m^2(t)]^{1/2} \quad , \end{aligned} \tag{2}$$

where R_s is the apparent radius of the emitting source, R_m is the apparent radius of the moon,

$$x_s(t) = [R_s^2 - R_m^2 + q^2(t)] \,/\, 2q(t) \quad , \tag{3}$$

$$x_m(t) = q(t) - x_s(t) \quad , \tag{4}$$

and q(t) is the distance between the centers of these disks.

The model of the solar panel current was used to derive the relative size, velocity, and distance of closest approach of sun and moon. No attempt was made to model the oscillations seen in

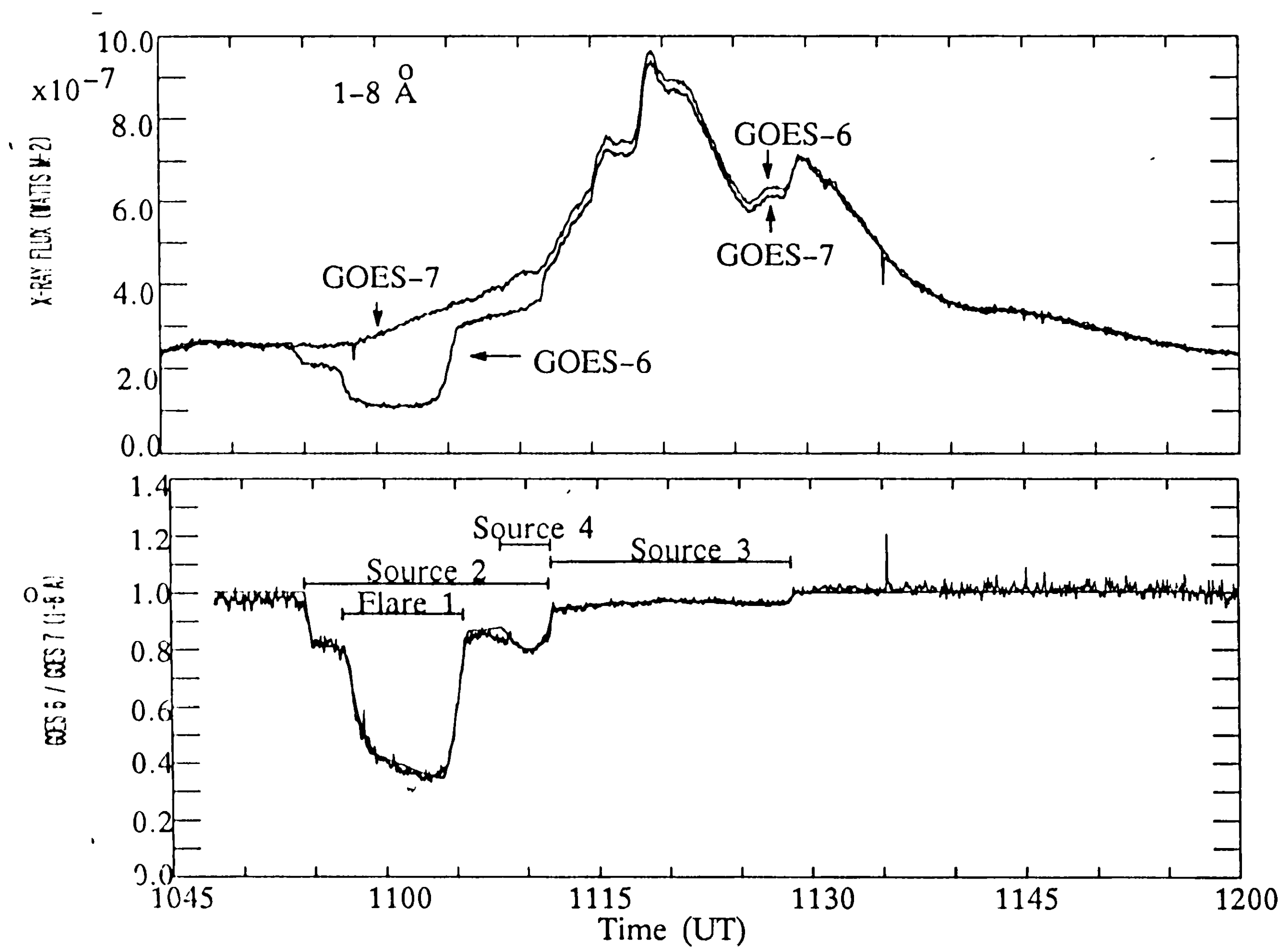

Fig 1. The observed 1-8 A X-ray fluxes and model fit. The ratio of the observed X-ray fluxes from the two satellites was modeled assuming four X-ray sources. The flux of only one source, the flare, was assumed to vary with time.

the solar panel current, which are caused by aliasing of the 100 rpm satellite spin and -3 sec sampling rate on cutouts in the solar panels. This geometry was then used in the models of both the 1-8 and 0.5-4 Å X-ray fluxes to derive the location, size, and flux of each X-ray source in these two bandpasses. To minimize the effects of flux changes due to the flare itself, the ratio of the same bandpass observed by the two satellites was used. Four sources were required to reproduce the observed ratio, given the geometry derived from the solar panel current.

Derivation of Plasma Properties

The temperature and emission measure for each of the four X-ray sources and for the flare were derived. The temperatures were derived from ratios of 0.5-4 and 1-8 Å fluxes. These temperatures were then used with the 1-8 Å fluxes to derive the emission measures ($\int n_e^2\, dV$). The properties of each of the X-ray sources, 1-4, were derived from the (constant) flux attributed to that active region. The properties of the flare were derived using one of three different assumptions about the amount of flux attributed to the flare:

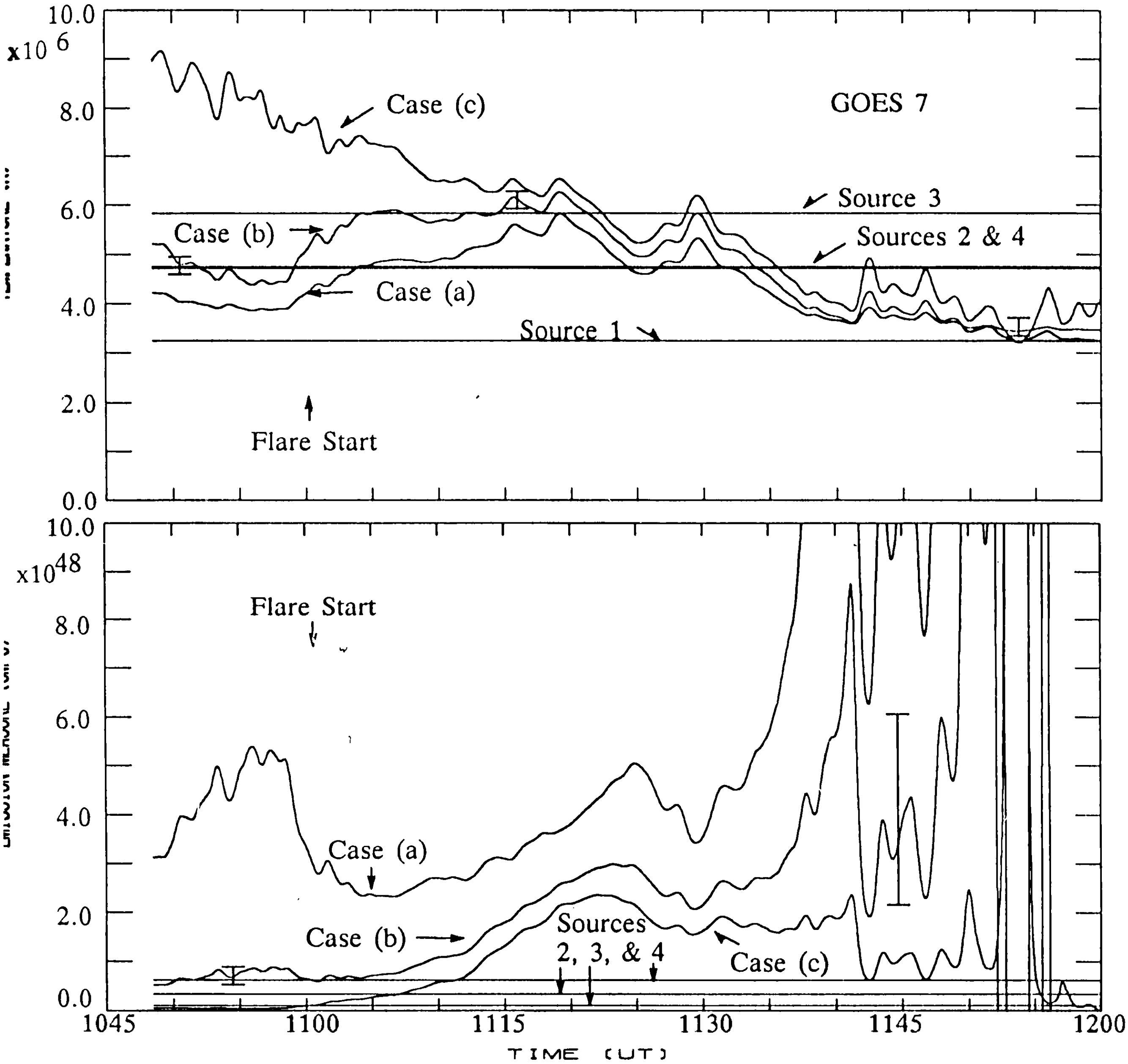

Fig 4. Smoothed temperatures and emission measures derived from the flux attributed to each source, 1-4, and for the flare using the three different assumptions, cases (a)-(c). Values for sources 2 and 3 are upper limits because these sources were not observed in the 0.5-4 A band. Also shown are typical error bars.

Case (a): All of the observed flux was attributed to the flare. In this case, the flare flux includes the contributions from all other sources, 1-4.

Case (b): All of the flux originating from the active region, source 1, is attributed to the flare. This is actually a version of assumption (a), but on the smaller scale of an active region.

Case (c): Only the flux above the quiescent levels was attributed to the flare. In this case, the flare flux is zero during non-flare times.

Discussion

The assumption (a), that the entire solar flux comes from the flare, ignores the effects of the other sources. It assumes that the observed flux originates in a single, homogeneous, isothermal region. The derived emission measures seem unphysical: Why should the emission measure decrease at the start of a flare? And why should it rise at the end of the flare?

The assumption (b), that the flare flux is the entire flux from active region that flared, implicitly assumes that the entire active region participated in the flare. This assumption produces more reasonable, but still questionable results: Why should the emission measure rise after the flux returns to quiescent levels?

The assumption (c), that the flux from the flare is only the flux above the quiescent level, implicitly assumes that the active region plasma and flare plasma are distinct. This is because this assumption forces the emission measure to be zero outside of flare times. The derived temperatures seem unphysical: Why should the temperature be dropping before the flare begins?

If, however, only part of the active region participated in the flare, then the derived plasma properties would be expected to lie between those found in assumptions (b) and (c). This case would be expected to give more physical results: That the temperatures and emission measures were not changing rapidly before and after the flare.

Conclusions

These results suggest that only part of the active region participated in the flare, *i.e.*, only a fraction of the active region brightened with the flare. If the flux is properly apportioned, then the derived plasma properties should exhibit behavior that is more intuitive: that the temperature and emission measure are constant both before and after the flare.

The need to determine the proper fraction of the flux that is due to the flare occurs not only for disk integrated detectors, such as the XRS on GOES, but also for any detector with a field of view that includes both flaring and non-flaring emissions. This need arises because we do not know the proper filling factor.

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